



Science and Technology in Australia 1977–78: Volume 2

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SCIENCE AND TECHNOLOGY IN AUSTRALIA 1977-78

A REPORT TO THE PRIME MINISTER
BY THE
AUSTRALIAN SCIENCE AND TECHNOLOGY COUNCIL
(ASTEC)

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AUSTRALIAN SCIENCE AND TECHNOLOGY COUNCIL
P.O. Box 52
CANBERRA, A.C.T. 2600

11 December 1978

My dear Prime Minister,

On 13 June 1978 ASTEC provided to you Volume 1A of its report on Science and Technology in Australia 1977-78. ASTEC now has the honour to present to you Volume 2 of its report. This Volume describes the present state of science and technology, especially research and development.

Yours sincerely,



G.M. Badger
Chairman



R.N. Robertson
Deputy Chairman

For and on behalf of:

Professor B.D.O. Anderson
Sir Samuel Burston
Dr L.W. Davies
Mr A.W. Hamer
Professor B.E. Hobbs
Mr B.T. Loton
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The Right Honourable Malcolm Fraser, CH, MP,
Prime Minister,
Parliament House,
CANBERRA A.C.T. 2600

PREFACE

ASTEC's report on Science and Technology in Australia 1977-78 is published in two volumes, and Volume 1 is in two parts. Volume 1A contains what might be termed background material on Australian science and technology, dealing with topics such as its history, gross expenditure on research and development, organisation of science and technology, and ASTEC's own history and procedures. Volume 1A also contains ASTEC's views and recommendations on areas of concern in science and technology which ASTEC believes should be brought to the early attention of the Government and others. These areas are fundamental research, industrial research and development, marine sciences and technologies, and health. Volume 1A was released in October 1978. Volume 1B completes the deliberative part of the report, and contains ASTEC's views on agriculture and forestry, mineral resources, manufacturing industry, services, and the environment.

Volume 2 contains 25 chapters, each describing the present position in a particular field of science and technology. The preparation and organisation of these 25 chapters is explained further in Chapter 14, 'Introduction to Volume 2'. In arriving at its conclusions and recommendations as expressed in Volume 1, ASTEC has made use of the factual, descriptive material collected for presentation in this volume. As a guide to the reader who wishes to look beyond this volume to the prescriptive material of Volume 1, the following chapters of this volume relate to the material of Volume 1A:

Chapter 15	Organisation of Australian Science and Technology
Chapter 16	International Relations, Liaison and Aid
Chapter 17	Fundamental Research
Chapter 21	Marine Sciences
Chapter 22	Coastal and Ocean Engineering
Chapter 39	Health

ASTEC's comments on other information in this volume can be found in Volume 1B.

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CHAPTER 14

INTRODUCTION

14.1 PREAMBLE

14.1.1 The rationale for the preparation of the ASTEC Report on Science and Technology in Australia 1977 is presented in Chapter 2 of Volume 1 of this Report. The choice of subjects on which position papers, describing the present state of science and technology in Australia, would be prepared, and the selection of expert consultants or co-ordinators to prepare them, is also described in Chapter 2. This chapter explains in some more detail the preparation of the position papers, and the method by which they were reviewed prior to inclusion as the following chapters of this volume.

14.1.2 Guidelines for the preparation of position papers were prepared by the ASTEC Secretariat. These covered matters such as the structure, extent of coverage and the degree of detail to be attempted by authors. Points which were particularly emphasised are listed below:

- . contributors of position papers were asked to emphasise research and development, with information on broader aspects of science and technology to be included wherever necessary to provide context;
- . the position papers were to include sections on: general background, covering a description of the area surveyed; material on policies, agreements and overall organisation of R&D in the area, and funding arrangements; on the conduct of R&D including descriptions of major research establishments and of major programs; and on conclusions and recommendations, in which the author could express his view on the state of R&D in the area surveyed. These conclusions were used by the Council to develop material for Volume 1 of the Report;
- . contributors were asked to concentrate their attention on descriptive material, using available quantitative information only as an indication of the extent of the arrangements described;
- . a comprehensive 'census' approach using wide distribution of questionnaires was to be avoided as far as possible. Authors were urged to make the fullest use of material already available, and to obtain material by personal contact with individuals and organisations;
- . brevity was essential, to avoid the total length of the volume becoming excessive.

14.1.3 In the event, of course, different areas under study required different methods of survey by authors, and not all position papers could adhere closely to the guidelines. The Council believes, however, that a reasonable degree of uniformity of coverage has been achieved across the chapters of this volume, especially when the diversity of material to be covered, and the relatively short time available to consultants, are considered.

14.1.4 Once position papers were completed, they were reviewed, to obtain information and opinion on their contents from as wide as practicable a range of experts. A member of Council was appointed co-ordinator of the review of each position paper, and each member assembled a small review working party, with membership selected so as to ensure a balance as far as possible across interested sectors. The review working party then met, usually with the contributor of the position paper, to discuss in detail the accuracy and coverage of the paper, to suggest amendments and additions and to form group judgements on the state of the area surveyed, including recommendations for future action. The outcome of the review process was usually in two parts: a reworking, usually by the author, of the factual part of the report, and the preparation by the Council member involved of a paper of comments, conclusions and recommendations on the area surveyed, to be used as an input to the relevant chapter of Volume 1. As well as this review process, Council members in some cases circulated position papers to expert individuals and organisations, seeking further information and opinion.

14.1.5 The final step in preparation of this Volume was editing to bring position papers as far as possible into a uniform format.

14.2 CAVEATS

14.2.1 It is inevitable that any classification system which divides science and technology into 'subject matter' or 'end use' areas, will contain some boundaries which cut across existing organisational arrangements, or traditional methods of grouping scientific activity. This has occurred in the ASTEC review, and has led to the dangers of gaps in coverage (areas of R&D and technology which are not covered) and of overlaps (areas which are considered from different viewpoints in different chapters). The problem of gaps in coverage is compounded by the need for brevity, and for a broad overview, which was impressed upon authors at the outset, and which was a primary consideration in subsequent review and editing stages. It should be noted that the chapters of this volume are a condensation of very substantial amounts of information available to authors and to the ASTEC Secretariat.

14.2.2 These deficiencies are recognised, but ASTEC considers that timely reporting was most important in the preparation of this review and, taking into account that it is the first attempt to provide such a coverage

of Australian science and technology, believes that the coverage provided is satisfactory. The general reader should use this Volume as a guide, rather than a compendium. ASTEC would be pleased to hear from specialists in the various fields covered if they believe that they can provide information and comment which would be of additional value to ASTEC in its future activities.

14.2.3 While appreciating greatly the help of all those involved, as detailed below, the final responsibility for all the material contained in this report lies with ASTEC alone.

14.3 ACKNOWLEDGEMENTS

14.3.1 ASTEC wishes to thank all those who were involved in the preparation of position papers and/or chapters of this volume. There were, of course, others too numerous to be mentioned here who were involved in a less-prominent way, and who can only be thanked collectively.

Contributors of position papers

14.3.2 This list records those who prepared the original versions of position papers. Many of these contributors enlisted help on an informal basis from within their own organisations or elsewhere. It is stressed that these authors produced the original versions of position papers only. The papers were subject to the review described in 14.1.4 above, and the views expressed in Volume 2 are not necessarily those of the authors listed here.

<u>Position Paper</u>	<u>Contributor</u>
Aeronautics and Aerospace	Mr F.G. Blight, Chief Superintendent, Aeronautical Research Laboratories, Defence Science and Technology Organisation, Department of Defence.
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Fundamental Research	Department of Science.
Health	Commonwealth Department of Health.
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Water Resources	Secretariat, Australian Water Resources Council, Department of National Development.
Wood Products	Mr W.H. Algar, Research Manager, Australian Paper Manufacturers Ltd.

Members of review working groups

14.3.3 The members of the review working groups listed here are those who attended a meeting or meetings of working groups or who provided their comments in writing. ASTEC wishes to thank them, and their organisations, where applicable, for their contribution to this Report.

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Agriculture	Sir Samuel Burston (Council member); Dr D. Hore, Assistant Director-General, Department of Agriculture, Victoria; Dr T. Scott, Chief, CSIRO Division of Animal Production.
Atmospheric Sciences	Professor B.E. Hobbs (Council member); Professor C.H.B. Priestley, Former Chief, CSIRO Division of Atmospheric Physics; Dr R.K. Steedman, R.K. Steedman and Associates, Perth; Dr W.J. Gibbs, Director, Bureau of Meteorology; Mr J. McAlpine, CSIRO Division of Land Use Research. Additional assistance was received from: Dr R. Janssen, Department of Meteorology, University of Melbourne; Professor B. Morton, Professor of Applied Mathematics, Monash University; Dr J. Zillman, Bureau of Meteorology; Dr B. Tucker, Chief, CSIRO Division of

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- Health Sir Gustav Nossal (Council member); Professor A. Basten, President, Australian Society for Medical Research; Professor C.I. Johnston, Department of Medicine, Monash University; Dr K.W. Edmondson, Secretary, National Health and Medical Research Council.
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- International Relations, Liaison and Aid Professor G.M. Badger (Council member); Professor L.G. Ada, Foreign Secretary, Australian Academy of Science; Dr H. Higgins, Assistant Chief, CSIRO Division of Chemical Technology; Mr R. Stensholt, Australian Development Assistance Bureau.
- Marine Sciences ASTEC Marine Sciences sub-committee (see under 'Coastal Engineering').
- Metal Products and Machinery Mr B.T. Loton (Council member). Drs R.G. Ward and H.C. Coe (the Broken Hill Pty Co Ltd) Substantial additional assistance and information

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Wood Products

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The ASTEC Secretariat

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AUSTRALIAN
RESEARCH

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on the South Coast
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CHAPTER 15

ORGANISATION OF AUSTRALIAN SCIENCE AND TECHNOLOGY

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THE
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ANNUAL REPORT

1977

CHAPTER 15
ORGANISATION OF AUSTRALIAN SCIENCE
AND TECHNOLOGY

15.1 INTRODUCTION

15.1.1. This chapter outlines the overall organisation of science and technology in Australia, concentrating more on the interconnections between the various sectors (government, both Commonwealth and State, tertiary education, private enterprise and private non-profit), than on the details of the organisation of the individual agencies which advise, fund, co-ordinate or perform R&D. Material on these agencies can be found in other chapters of this report, and in the standard published references in this area [1,2,3]. Comments on the adequacy, or otherwise, of organisational arrangements in various areas, can be found in the appropriate sections of Volume 1.

15.1.2 In Australia the organisations active in science and technology comprise

- . Commonwealth and State Governments - statutory bodies and departments;
- . tertiary education institutions - universities, colleges of advanced education, and institutes of technology. Some of these operate consultant companies which draw on the expertise of the staff of their parent institutions;
- . business enterprise - principally primary and extractive industries, and processing and manufacturing industries, and associated research organisations;
- . private non-profit research institutions;
- . academies and professional associations;
- . interface organisations - research associations, inter-government councils and standing committees, and trust funds.

THE OVERALL ROLE OF GOVERNMENT

15.2.1 Government responsibility for science and technology in Australia is shared by State and Commonwealth Governments. The Commonwealth Government, however, has exclusive responsibility for defence and telecommunications science and technology. State Governments have a particular, but not exclusive, interest in applied research and in the application of science, and thus play a major role in agriculture, fisheries, forestry, mining, and water resources. Table 15.1 shows State and Commonwealth Government departments responsible for some of those functions which are of interest to this review of science and technology [4].

15.2.2 Numerous inter-governmental bodies have been established to promote and facilitate co-operation between the Commonwealth and State Governments, and to co-ordinate, as far as practicable and desirable, activities of the governments. The most important of these are the intergovernmental Ministerial Councils, including the Australian Agricultural Council, Australian Environmental Council, Australian Fisheries Council, Australian Forestry Council, Australian Minerals and Energy Council, Australian Transport Advisory Council, Australian Water Resources Council, and the Council of Nature Conservation Ministers. These Councils are concerned primarily with more general economic, social or environmental goals, but also pay some attention to underlying science and technology matters.

15.2.3 The inter-governmental Ministerial Councils are assisted by standing committees of officials. Frequently, expert working groups and sub-committees are established to consider particular specialised aspects of a Council's broad field of interest and to advise the Council through the relevant standing committee.

15.2.4 Ministerial Councils do not directly undertake research or the provision of services, although such activities are commonly pursued within agencies coming under the control of individual members. In some instances, Councils have control of research funds and provide grants or arrange contracts in support of research relevant to their particular fields of interest. In some scientific and technical fields, not coming directly within the ambit of the Ministerial Councils, there are standing arrangements, at agency level, for consultation and promotion of co-operation. The Electricity Supply Association of Australia is an example.

ADVICE AND CO-ORDINATION

15.2.5 In addition to inter-governmental agencies, parliamentary and official advisory bodies have been established to deal with specific activities, interests and responsibilities of the Commonwealth government and its agencies, and to advise on Government support of tertiary education and of industry. To indicate the range of functions encompassed by such bodies, a few examples follow.

15.2.6 Parliamentary committees with an interest in science and technology are the Senate Legislative and General Purpose Standing Committees on Science and the Environment, and on National Resources, and (to a lesser extent) the House of Representatives Standing Committees on Environment and Conservation, and on Road Safety. The Senate Standing Committee on Science and the Environment has a very wide reference, covering policy and R&D efforts in the physical, social and life sciences, and has oversight of the problems of pollution and preservation of the environment. It produced a progress report on policy matters for science and technology in November 1977, and is currently engaged in an open inquiry into industrial R&D, and an investigation of developments in the Alligator Rivers region of the Northern Territory, particularly the likely effects of uranium mining on the Kakadu National Park. The Senate Standing Committee on National Resources produced a report on solar energy in 1977, and is currently investigating the Commonwealth's role in water resources.

15.2.7 The Australian Research Grants Committee (ARGC) assesses proposals (almost all from tertiary education) in the social sciences and humanities, in the physical sciences, chemical sciences, biological sciences, earth sciences, and in engineering and the applied sciences. The prime criterion for support is the overall scientific excellence of the proposal taking into account both the project and the investigator. Grants are made without regard to the distribution of funds between the different disciplines. The ARGC reports to the Minister for Science.

15.2.8 The National Health and Medical Research Council (NH & MRC) membership consists of representatives of Commonwealth and State governments, members of medical and dental groups and eminent persons appointed by the Commonwealth Government. The functions of the NH & MRC include provision of a framework for inter-governmental collaboration, provision of advice on public health legislation and administration, and other matters, including medical research and the merits of reported cures or methods of treatment, and the awarding of grants in support of medical and dental research. The NH & MRC reports to the Minister for Health.

15.2.9 The Tertiary Education Commission (TEC) was formed in 1977 to replace the Universities Commission, the Commission on Advanced Education, and the Technical and Further Education Commission. The TEC, which reports to the Minister for Education, has the function of advising the Government on financial assistance in relation to tertiary education, including research in tertiary education institutions, and on the overall balanced development of Australian tertiary education.

TABLE 15.1
FUNCTIONAL RESPONSIBILITIES OF COMMONWEALTH
AND STATE GOVERNMENT DEPARTMENTS

<u>FUNCTION</u>	<u>GOVERNMENT AND DEPARTMENT</u>						
	<u>Commonwealth</u>	<u>NSW</u>	<u>Victoria</u>	<u>SA</u>	<u>Queensland</u>	<u>WA</u>	<u>Tasmania</u>
Agriculture	Primary Industry	Agriculture	Agriculture	Agriculture and Fisheries	Primary Industries	Agriculture	Agriculture
Forestry	Primary Industry	Conservation and Water Resources	State Forests	Woods and Forests	Lands, Forests and National Parks	Forests	Agriculture (Forestry Commission)
Fishing	Primary Industry	Conservation and Water Resources	Conservation	Agriculture and Fisheries	Aboriginal Advancement and Fisheries	Fisheries and Wildlife	Agriculture
Earth (Geological Surveys)	National Development	Mines and Energy	Minerals and Energy	Mines	Mines and Energy	Mines	
Mining and Energy	National Development; Trade and Resources	Mines and Energy	Minerals and Energy	Mines	Mines and Energy	Mines	Mines (including Hydro-Electric Commission)
Water Resources	National Development	Conservation and Water Resources	Water Supply	Engineering and Water Supply	Water Resources	Mines	Rivers Water and Supply Comm.

<u>FUNCTION</u>	<u>Commonwealth</u>	<u>NSW</u>	<u>Victoria</u>	<u>SA</u>	<u>Queensland</u>	<u>WA</u>	<u>Tasmania</u>
Environment	Environment, Housing and Community Development	Planning and Environment, Lands	Conservation; Health	Environment	Lands, Forestry and National Parks	Conservation and Environ- ment	Environment
Coastal Engineering	Construction	Public Works and Ports	Conservation	Marine and Harbours	Tourism and Marine Services	Public Works	
Construction	Construction	Public Works and Ports	Public Works	Engineering and Water Supply	Works and Housing	Public Works	Housing and Cons- truction
Transport	Transport	Transport and Highways	Transport	Transport	Transport	Transport Commission	Transport Commission
Telecommun- ications	Postal and Telecommunications; Postal Commission; Telecommunications Commission						
Health	Health	Health	Health	Public Health	Health	Public Health	Health

15.2.10 The Australian Industrial Research and Development Incentives Board (AIRDIB) administers the Industrial Research and Development Incentives Act (prior to 1976 the Industrial Research and Development Grants Act) under which industrial R&D grants are paid to Australian manufacturing and mining companies. The broad areas which have benefited under the scheme have been basic metal products, industrial machinery and equipment, electric and electronic apparatus, transport and chemicals. AIRDIB reports to the Minister for Productivity.

15.2.11 Advisory bodies are concerned with scientific and technological aspects of their particular fields of responsibility. In order to achieve, at the national level, integration of advice, relative assessment of priorities, and the development of criteria and broad strategies for future policies, three national advisory bodies have recently been established: the Australian Science and Technology Council (ASTEC), discussed in detail in Chapter 2; the National Energy Advisory Committee (NEAC) founded as an interim committee in 1977, which advises the Minister for National Development on matters relating to national energy policy; and the Australian Manufacturing Council (AMC), founded in 1977 to replace the Manufacturing Industry Advisory Council, which is served by some eleven advisory councils and which advises the Minister for Industry and Commerce on matters of industry policy.

15.2.12 Some State governments have established science and technology advisory bodies (NSW) and energy advisory bodies (Victoria, Western Australia, Queensland). The latter are of long standing, reflecting State responsibility in the energy field. The New South Wales Science and Technology Council deserves special mention as the first such advisory body established by a State government in Australia. It advises the Premier of New South Wales, and conducts studies relevant to science and technology of interest to the State government.

15.2.13 Learned societies and professional bodies are also sources of advice to government on science and technology issues; indeed many of these bodies have organised their committee structure so that they may, on their own initiative or in response to requests, offer comment and counsel on matters falling within their particular field of interest. The Australian Academy of Science, through sectional and standing committees as well as ad hoc committees is a significant link in the chain of communication between scientist and government. Communication between government and the technology area of the science-technology spectrum will be facilitated by the recently established (1976) Australian Academy of Technological Sciences.

15.2.14 The most broadly based of the scientific societies is the Australian and New Zealand Association for the Advancement of Science (ANZAAS). Its Commission for Science Policy, during its period of operation, provided a focus for policy advice from within the broad coverage of ANZAAS.

15.2.15 Increasingly, other professional bodies with more specific charters are giving attention to matters of science and technology policy.

These include the Royal Australian Chemical Institute (RACI), the Institution of Engineers, Australia, and the Australian Institute of Physics. The Federation of Australian University Staff Associations (FAUSA) concentrates on issues specifically affecting the university sector.

15.2.16 There are several groups within the industry sector, for example the Australian Industrial Research Group (AIRG) and some specialist panels (Industry Advisory Councils) of the Australian Manufacturing Council (AMC), which from time to time provide advice to government on industrial research and development.

FINANCIAL SUPPORT OF SCIENCE AND TECHNOLOGY

15.2.17 Comprehensive data on the resources devoted to overall scientific and technological activity in Australia are not available; however, the Department of Science's Project SCORE [5] provides data on research and development expenditure and manpower, most recently for 1973-74.

15.2.18 The Project SCORE data reveal that for 1973-74 total expenditure on R&D in Australia in the natural and social sciences and humanities was of the order of \$651million, approximately equivalent to 1.3% of the Gross Domestic Product (\$50,557million) for that year. The sources of these funds, their apportionment between various sectors of R&D performance, and their application to broad objectives are shown in Figure 15.1. Similarly broad information for 1973-74 on manpower is shown in Table 15.2.

15.2.19 It can be seen that Commonwealth and State governments occupy the dominant positions in the funding and performance of R&D. The following facets of Gross National Expenditure on R&D (GERD) are also worthy of note:

- . 91% of expenditure was for work in the natural sciences;
- . the three most significant objective sub-groups were: advancement of science, (accounting for 35% of expenditure for the natural sciences), primary industry (23%), and defence (15%),
- . in the Business Enterprise sector, manufacturing industry accounted for 80% of R&D expenditure, about half of which was distributed approximately equally between fabricated metal products and transport equipment.

15.2.20 For the purpose of broad comparison across the sectors, Table 15.3 shows manpower and money resources devoted to some of the more important R&D organisations and laboratories in Australia. Figures are inevitably drawn from widely varying sources, and differences in definitions between these sources hampers comparison to a certain extent. Nonetheless, Table 15.3 provides an interesting comparison of the intensity of research efforts among organisations in different sectors.

FIGURE 15.1
DISTRIBUTION OF TOTAL EXPENDITURE ON R&D
SOURCES, SECTORS, OBJECTIVES

SOURCES OF FUNDS

		\$m	%
Australian Funds \$655m	Common-wealth Government	348	52
	State Government	65	10
	Business Enterprise	234	35
	Private Non-profit	7	1
	Overseas Funds	12	2
Total		666	100

SECTOR OF PERFORMANCE

		\$m	%
Australian Performance \$651m (GERD)	Common-wealth Government	202	30
	State Government	73	11
	Business Enterprise	228	34
	Higher Education	142	21
	Private Non-profit	6	1
Overseas Performance		16	2
Total		666	100

OBJECTIVE GROUPS

	\$m	%
Defence	56	8
Economic Development	400	60
Community Welfare	38	6
Advancement of Knowledge	171	26
Total	666	100

TABLE 15.2
BROAD FEATURES OF MANPOWER DEVOTED TO
R&D IN AUSTRALIA 1973-74

<u>Sector</u>	<u>Man-years</u>	<u>% of R&D Manpower</u>	<u>% of Australian Workforce</u>
Tertiary Education	17,111	32	0.29
Private Enterprise	14,710	28	0.25
Commonwealth Government	14,516	27	0.25
State Government	6,382	12	0.11
Private Non-Profit	<u>578</u>	<u>1</u>	<u>0.01</u>
Totals	<u>53,297</u>	<u>100</u>	<u>0.91</u>

Broad Objective of R&D Effort

Economic Development	59%[6]
Advancement of Knowledge	26%[7]
National Security	9%
Community Welfare	6%

Source: Project SCORE, Research and Development in Australia 1973-74,
Vol.2, p.3.

TABLE 15.3

R&D RESOURCES OF SOME MAJOR RESEARCH ORGANISATIONS

1976-77

<u>Organisation</u>	<u>Professional/ Research Staff</u>	<u>Technical/ Support Staff</u>	<u>Budget (\$million)</u>
<u>Commonwealth</u>			
CSIRO	2580	4387	147.7
Atomic Energy Commission	365	927	24
Telecom			
- Research Laboratories	160	340	13
- All Research	233	413	28
Defence Science and Technology Organisation	1100	4100	89
<u>State Governments</u>			
NSW Dept of Agriculture	430	N/A	25.7
Vic Dept of Agriculture	303	N/A	12.1
Qld Dept Primary Industries	505	N/A	N/A
<u>Industry</u>			
BHP Co Ltd and subsidiaries	196	326	10.6
ICI Australia Ltd	260	280	10.8
Dulux Australia Ltd	20	150	2.6
Total ICI group	280	430	13.4
<u>Private Non-Profit</u>			
Walter and Eliza Hall Institute of Medical Research	47	120	3.25
Howard Florey Institute of Experimental Physiology and Medicine	31	45	1.4
<u>University</u>			
ANU Institute of Advanced Studies			
Research School of Biological Sciences	77	166	N/A
John Curtin School of Medical Research	99	235	N/A
Research School of Physical Sciences	98	190	N/A
Research School of Chemistry	72	115	N/A
Research School of Earth Sciences	32	62	N/A

Sources: Annual Reports and private communications.

NOTES AND REFERENCES

1. J. Ronayne and G.J. Neale (Eds.) Guide to World Science, vol. 18, 'Australia and New Zealand', Francis Hodgson, London, 1974.
2. 'Reviews of National Science Policy; Australia', OECD, Paris, 1977.
3. 'Commonwealth Government Directory 1977' Australian Government Publishing Service, Canberra 1977, and similar directories of State government organisations.
4. Table 15.1 is derived from 'The Governments of Australia' (Third Edition), International Public Relations Pty Ltd, Canberra, 1976.
5. Department of Science. Project SCORE, 'Research and Development in Australia', 1973-74. Australian Government Publishing Service, Canberra, 1977.
6. This figure is derived by assuming that all R&D effort in the private enterprise sector is devoted to economic development.
7. This figure is obtained by assuming that all R&D effort in the tertiary education sector is devoted to advancement of knowledge.

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Photograph: Co-operative research involving Australian and Indonesian staff at the Centre for Animal Research and Development, Bogor, Indonesia (Photograph courtesy CSIRO)

CHAPTER 16

INTERNATIONAL RELATIONS, LIAISON AND AID

16.1 INTRODUCTION

16.1.1 This chapter briefly examines the mechanisms for Australia's international co-operation, liaison and aid programs in science and technology.

16.1.2 The spectrum of mechanisms for international co-operation in science ranges from contacts which are developed by individuals through literature, overseas study and the like, through bilateral agreements between governments to formal multilateral arrangements. These various forms of interaction are, to a large extent, complementary although there is considerable overlap in both objectives and functions. This chapter is primarily concerned with the more formal end of the spectrum. However, it should be noted that the majority of international contacts are informal and, in order to preserve the perspective, reference is also made, where appropriate, to informal activities.

16.1.3 Formal Australian involvement in international scientific and technological co-operation takes place not only through arrangements made or co-ordinated at government level but also through arrangements made by individual institutions both governmental and non-governmental. The former are dealt with in some detail in the following paragraphs; discussion of the latter is more cursory and is intended to be illustrative rather than comprehensive.

16.2 INTERGOVERNMENTAL COLLABORATION

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16.2.1 Australia's main government channels for collaboration with other countries in the fields of civil science and technology are:

- . bilateral agreements for scientific and technological co-operation;
- . multilateral co-operative programs which arise from membership of international organisations (such as the United Nations (UN) agencies and associated organisations, and the Organisation for Economic Co-operation and Development (OECD));

- specific subject agreements;
- scientific liaison offices attached to embassies; and
- scientific and technological aspects of the Australian Development Assistance Program (described in section 16.4).

Bilateral agreements

16.2.2 The establishment of broad-scope, bilateral, co-operative, science programs under formal agreements is a relatively recent innovation in advancing foreign relations and supporting science and technology. Governments had little direct involvement in international co-operation in science until 1945 and, for some time after that, bilateral arrangements were limited to specific fields such as atomic energy (such agreements exist between Australia and the USA, Canada, and Japan). It was not until 1961 that the USA established its first bilateral co-operative science program (with Japan). It established further bilateral programs in 1967 (with Italy) and in 1968, when the US-Australia Agreement for Scientific and Technological Co-operation was signed (Australia's first such agreement). Australia has subsequently entered into science agreements (Appendix 16.1) with the USSR (1975), India (1975) and the Federal Republic of Germany (1976). The possibility and desirability of agreements with some other countries such as Japan, France and Brazil have been considered recently. Australia has also signed a number of cultural agreements (such as those with Indonesia, France and Iran) which specify scientific co-operation, principally in academic fields, as one of a number of areas for potential collaboration.

16.2.3 Bilateral agreements are generally intended to stimulate co-operative activity between countries across the spectrum of science and technology. They should play major roles in:

- promoting activities which cannot readily be undertaken through existing informal contacts (for example a collaborative feasibility study on energy technology); and
- facilitating contact between scientific communities which are closed to each other by language or political barriers.

16.2.4 A further motivation, basically political, is to establish and strengthen relations with another country. In instances where there are limited opportunities for dialogue in other fields, scientific co-operation, in so far as it is non-sensitive, could play a bridging role. There may of course be some danger of conflict or tension between the operational and the international relations motives for an agreement. Irrespective of the motive for scientific co-operation, it is desirable that scientific value be emphasised when areas of co-operation are chosen.

16.2.5 The more important functions served by Australia's (intergovernmental) bilateral agreements are:

provision of a formal setting for inter-agency agreements, such as between the Department of Science and the US National Aeronautics and Space Administration concerning Landsat 2;

provision of a mechanism by which individuals or institutions can gain access to facilities owned/operated by a foreign Government - e.g. under the Australia/Federal Republic of Germany (FRG) Science and Technology Agreement a team of Australian scientists participated in a co-operative, marine geological and geophysical cruise on board the West German research vessel *Valdivia*; the very long baseline interferometry experiment between Australia, the USSR and the USA facilitated by the Australia/USSR agreement;

facilitating the sharing of knowledge in areas where a similarity of interests is evident but where informal contacts do not easily develop, (for example, a joint Australian-Federal Republic of Germany (FRG) feasibility study of coal liquefaction is at present under consideration. Discussions were initiated during a visit by an FRG delegation sponsored in relation to the Australia-FRG agreement);

providing a funding mechanism for binational seminars and workshops and for exchanges of working scientists to conduct co-operative activities (for example, under the US-Australia agreement, in 1976-77 there were 12 visits by Australian scientists to the US, 30 visits by US scientists to Australia and 5 seminars (3 in Australia), and under the Australia-USSR agreement there were 25 visits by Australian scientists and 20 by Soviet scientists in 1976-77).

16.2.6 Perhaps the most important aspect of international contact in science and technology is the transfer of information. This takes place mainly through the literature, through person-to-person contact, and institution-to-institution contacts. These contacts are initiated, and to some extent maintained, through overseas travel for postgraduate and postdoctoral study, sabbatical leave, study visits, and attendance at symposia. Bilateral agreements can provide an infrastructure to promote such activities. Examples of how this can be achieved include the supporting of symposia and the provision of opportunities for contact in areas where person-to-person contacts are not easily made.

Specific subject agreements

16.2.7 In addition to bilateral agreements, which are generally fairly broad in scope, specific purpose arrangements and understandings have developed between agencies in response to specific needs. A major example is the Anglo-Australian Telescope Board which is a binational body set up under an agreement between the Australian and United Kingdom Governments. Other such agreements are with France and Brazil (agency-to-agency agreement to study entomology), the NASA agreement

with the USA, and that with Japan for a geostationary meteorological satellite.

Multilateral co-operation

16.2.8 Australia participates in a variety of international programs in the field of civil science and technology as a consequence of its membership of inter-government organisations such as:

- the United Nations, its specialised agencies, and associated organisations;

- the Organisation for Economic Co-operation and Development (OECD);

- the Commonwealth of Nations; and

- the Association for Science Co-operation in Asia (ASCA).

The Department of Foreign Affairs has overall responsibility for co-ordinating Australian participation in these inter-governmental bodies, but primary responsibility for Australian involvement in particular organisations is often undertaken by the Department with equivalent interests, for example, the Department of Primary Industry has responsibility for the UN Food and Agriculture Organisation, and the Department of Science for the UN World Meteorological Organisation and for ASCA.

16.2.9 In addition, Australia participates in scientific projects involving international co-operation by virtue of its adherence to the Antarctic Treaty. Another important aspect of Australia's participation in multilateral bodies is its funding of programs undertaken by these bodies for the benefit of developing countries. This is discussed further in section 16.4.

16.2.10 Many of the collaborative activities undertaken under multilateral arrangements are concerned, to a large extent, with the setting of international scientific and technical standards (for example in the fields of weights and measures, meteorology, telecommunications, atomic energy), with exchanges of information and experience, and with comparative studies of various policy approaches, at national governmental level, to the organisation and support of science and technology. Other multinational arrangements involve participation in experiments, such as the Global Atmospheric Research Program and the International Geological Correlation Program.

16.2.11 A representative list of international organisations, departmental responsibility, and function is given in Appendix 16.2.

Liaison offices

16.2.12 Since 1940, when a British scientist was accredited to Washington to co-operate in the development of radar and atomic science, the

diplomatic accreditation of scientific attaches or counsellors has become an established practice in international diplomacy. Japan, France, South Africa (agriculture and technology) and the United States of America maintain posts of this nature in Australia, while Australia has posts in London, Moscow, Tokyo and Washington. In addition, Australia maintains a science and environment representative as part of its permanent OECD delegation.

16.2.13 Officers occupying these posts perform a number of important functions, such as:

- . collection and dissemination of information, either in response to requests from individual Australian scientists, or for more general circulation to the Australian scientific community;
- . action as agents for Australian bodies (principally CSIRO) in matters such as recruitment of staff;
- . representation at conferences;
- . arranging meetings and hospitality, and overcoming bureaucratic barriers, on behalf of visiting senior scientists and science administrators;
- . providing advice to diplomatic missions on questions involving science and technology.

These functions incorporate activities ranging from elementary office support to those in which scientific liaison officers play a role almost equivalent to that of a 'roving ambassador' for Australian science.

16.2.14 Under the present CSIRO legislation, CSIRO is required to act as a means of liaison between the Commonwealth and other countries in most matters of scientific research. Most of the holders of the scientific attache positions have, until now, been CSIRO officers paid by CSIRO and supported by locally-hired staff employed by the Department of Foreign Affairs. While the officers have diplomatic status and represent all civil science (excluding nuclear energy), the representatives in earlier years largely tended to concentrate their attention on matters of concern to CSIRO. In the past few years, they have broadened their base of responsibility to provide services to an increasing number of government departments and authorities. The Counsellor (Scientific) in Moscow has a major role in facilitating the whole range of bilateral scientific relations between the USSR and Australia, particularly the Australia-USSR Science Agreement.

16.2.15 The USA and UK offices are long established; the Moscow and Tokyo offices are quite recent although, at one stage during World War II, Australia had a scientific attache in Moscow. The staffing of the London and Washington offices has recently been severely reduced; this has forced the liaison officers to reduce their range of activities.

16.2.16 The Australian Atomic Energy Commission (AAEC) maintains representation in the Australian missions in London, Washington, Vienna and Tokyo under the same conditions as those outlined above for scientific liaison officers. The London and Washington offices are long established. The Vienna post is more recent and the Tokyo post the most recently established. The activities of the representatives in London, Washington and Tokyo are similar to those described for the CSIRO representatives, but applied to the field of nuclear science and technology. The officer in Vienna is largely occupied in liaison with the International Atomic Energy Agency, whose headquarters are in Vienna. The officer in London has a considerable involvement with the Nuclear Energy Agency of the OECD, whose headquarters are in Paris. Staffing in Washington, Tokyo and London has recently been severely reduced with a consequent reduction in the scope of the activities of liaison officers.

DEFENCE

16.2.17 The Defence Science and Technology Organisation actively maintains access to overseas technology both as an aid to particular tasks and as a means of extending Australia's defence technology base generally. Such access depends on an ability to contribute, and on the existence of expert recipients in Australia to obtain and understand the data. The Department of Defence has scientific and technical representatives in London and Washington.

Bilateral agreements

16.2.18 The Department of Defence has broad, umbrella agreements with the USA and the UK for co-operation in defence R&D. The USA agreement has been operating since 1968. A formal agreement with the UK was effected in 1978 and traditional links have existed dating back to World War II and beyond.

16.2.19 Bilateral agreements are used in specific areas where collaborative effort will be of mutual benefit; the most notable are those dealing with surveillance both underwater and in the air.

16.2.20 Regular exchange of technical abstract bulletins occurs with the USA, UK and Canada. These permit Australian defence scientists to be aware of some 50,000 documents a year; many of these are restricted for reasons of national security and would not be available without the special arrangements.

Multilateral co-operation

16.2.21 The Technical Co-operation Program (TTCP) is the main body for Australia's multilateral co-operation in defence science and technology. The participating countries are United States of America, United Kingdom, Canada, New Zealand and Australia; the governing body consists of the Chief Defence Scientists of the member countries.

16.2.22 Subgroups in major technology areas manage the detailed work of TTCP. Australia participates in a large proportion of the areas covered by TTCP through membership, and participation, of senior practising scientists throughout the Defence Science and Technology Organisation.

16.2.23 The Commonwealth Defence Science Organisation (CDSO) is a body formed among Commonwealth countries to promote the better utilisation of resources in the defence sciences. In particular, exchange of scientific information and contact between scientists, is encouraged. Symposia are held at about three year intervals.

16.2.24 The Commonwealth Advisory Aeronautical Research Council (CAARC) promotes defence and civil aeronautical research in member countries, through pooling of resources, dissemination of information, facilitating interchange, secondment and visits of aeronautical scientists and through identification of problems of mutual interest.

16.2.25 The International Conference on Aircraft Fatigue (ICAF) has representation from about 20 countries in the western world. It deals with all unclassified aspects of aircraft fatigue, usually meeting twice a year.

16.3 NON-GOVERNMENT CO-OPERATION

16.3.1 Non-government co-operation in science and technology covers scientist-to-scientist contact, membership by Australia of major international science organisations, and institutional agreements and exchanges.

16.3.2 Scientist-to-scientist contacts are made through the literature; at international symposia; and during overseas visits, including those for higher degree and postdoctoral training. Co-operative projects are advanced by correspondence and by periods of study spent with colleagues, either overseas or in Australia. The workings of such arrangements appear to have been little studied.

16.3.3 Australia participates in the major international science organisations, typified by the organisations affiliated to the International Council of Scientific Unions (ICSU). The Australian Academy of Science is the Australian adhering body for ICSU and most of the international scientific unions. A list of ICSU affiliates adhered to through the Academy is at Appendix 16.3. The Australian Academy of Technological Sciences is investigating the possibility of contacts with other international bodies concerned with its areas of interest.

16.3.4 A number of Australian non-governmental institutions and organisations are involved in bilateral, and multilateral, arrangements for scientific and technical cooperation. Some examples are:

The Australian Academy of Science has an active, government funded, arrangement for scientific exchange with the Academia Sinica Peking (and it also has an agreement with the Japan Society for the Promotion of Science which has not yet been activated);

The Australian National University has an agreement for exchange of academic staff with Moscow State University.

16.3.5 Another important area in which non-government co-operation occurs is in the contacts between Australian industrial companies and those of other nations. These occur through various mechanisms. There are some formal, company-to-company agreements which provide for the interchange of technical information, expertise, and inventions. Technical information is supplied and interchanged between Australian subsidiary companies and their overseas parents. Scientists and technologists in Australian industry have, through overseas visits, established valuable contacts with their counterparts in overseas companies. The value of these mechanisms to Australian industry is difficult to estimate, but some Australian companies have indicated that their R&D effort is greatly enhanced through these international contacts.

16.4 CO-OPERATION WITH DEVELOPING COUNTRIES

16.4.1 Australia's development assistance program is the major channel through which Australia co-operates with developing countries in the field of science and technology, although transfer of Australian technology and scientific knowledge is also effected through the sorts of formal and informal channels described earlier. This section considers in detail development assistance programs and activities by Australia for the benefit of developing countries. Assistance is provided through bilateral programs between Australia and specific countries, and through Australia's involvement in multilateral international organisations.

16.4.2 Australia's scientific and technological relations with developing countries can be divided into two (not necessarily exclusive) categories: the first, or partnership category, involves scientific co-operation that is largely of mutual benefit, and occurs by such means as the Australia-India bilateral agreement. The second, or aid, category takes the form of scientific and technical development assistance activities, principally within the development assistance programs. One important distinction between the partnership category and the aid category is that, in the former, the scientific aspects of the co-operation are of primary importance. In the aid category however, the scientific and technological activities are usually a vehicle for aid, and not ends in themselves (unless, of course, the objective of the aid is for the country to become technologically self-sustaining in a particular area). Research projects in developing countries need to have a definite developmental aspect if they are to qualify for official Australian aid support.

CO-OPERATION UNDER THE BILATERAL AID PROGRAM

16.4.3 The Australian development assistance program is administered by the Australian Development Assistance Bureau (ADAB) which is attached to the Department of Foreign Affairs. The five basic components of the bilateral aid program are: aid to Papua New Guinea, project aid, food aid, education and training programs, and assistance for the activities of non-government organisations.

16.4.4 Many of the bilateral project and training activities are carried out on behalf of ADAB by Commonwealth Government instrumentalities such as CSIRO (by far the most heavily involved in this area), the Snowy Mountains Engineering Corporation and the Australian Atomic Energy Commission, by State Government Departments, by tertiary educational institutions, and by private consultants and business firms.

16.4.5 One of the basic aims of Australia's development assistance strategy is to promote the transfer of technology, expertise and information. Australia provides scientific and technological assistance under the aid program in terms of finished products, technical services, technological processes, training and research. It is estimated that, in 1976-77, some \$30million was spent on programs and projects of a wholly scientific and technological nature and a further \$70million on projects and programs that had scientific and technological components, in countries other than Papua New Guinea. Major recipients were Indonesia and other member countries of the Association of South-East Asian Nations (ASEAN), and countries in the South Pacific and South Asia. Aid to Papua New Guinea, which formed 60 per cent of total official aid in 1976-77, is largely given in the form of a grant for budget support and it is not possible to identify accurately the proportions of that assistance devoted to scientific and technical activities.

16.4.6 Emphasis is increasingly being placed on the role of research and technology in aid projects. In 1977-78, 24 bilateral projects, with an estimated total cost of \$85.3million, have research components. It is considered that \$30.8million, or 36% of total expenditure on these projects will be spent on R&D activities. The cost of the research components in these projects range from \$12,000 to several million dollars. More than 70% of the amount committed to research is allocated to 6 projects in Indonesia with the remaining expenditure spread among 18 projects in more than 10 countries.

16.4.7 Examples of research in aid projects include CSIRO's work on food, nutrition, animal research, agriculture and forestry. Among the CSIRO divisions involved are Food Research, Chemical Technology, and Tropical Crops and Pastures. These projects arise as a result of official requests to ADAB.

16.4.8 Training and education have formed a major part of Australia's aid program since its inception and they represent one of the most important means by which Australia is assisting developing countries in the fields of science and technology. During 1976 Australia financed 2462 students and trainees from developing countries who undertook training in Australia in a wide variety of scientific fields. Over 500 of these were undertaking research at Australian institutions. Australia is also host to possibly twice that number of home-government sponsored and private students who represent an indirect charge on the Australian taxpayer.

16.4.9 CSIRO plays a large role in this training of research personnel and, in the period 1974-76, over 200 trainees under the International Award Scheme spent periods of up to two years in CSIRO. The trainees come from a total of 41 countries with some 50% coming from India, Indonesia and Korea. In addition, CSIRO staff have been involved in on-site training overseas and in consulting with local authorities on planning, upgrading and reorganisation of local institutions.

16.4.10 Australia also assists a number of educational institutions in developing countries by providing lecturers, scholarships and equipment. Under the Australian Asian Universities Co-operation Scheme (AAUCS), which is co-ordinated through the Australian Vice-Chancellors' Committee (AVCC), assistance is given to a number of universities in Indonesia, Malaysia and Singapore. The Scheme provides for the secondment of Australian academic staff, the running of intensive short courses, fellowships for Asian university staff to study and carry out research in Australia, and small support projects such as assistance to libraries and laboratory services. The main emphasis is on agriculture and food production. Consideration is being given to expanding the scheme to Thailand and the Philippines.

R&D IN AUSTRALIA FOR THE BENEFIT OF DEVELOPING COUNTRIES

16.4.11 Research in Australia with the primary objective of benefiting developing countries has been limited. This has partly been due to the need to service Australia's own development needs and partly because of institutional and funding arrangements which have meant that the major thrust of Australian research for developing countries has been in the developing countries themselves under the aid program. For example, CSIRO is bound by its statute to direct its research to the problems of Australia, rather than overseas, industry, although it does undertake work funded by other bodies such as ADAB at the discretion of its Minister.

16.4.12 In spite of these limitations several programs have been, or are currently being undertaken. These include the CSIRO Division of Chemical Technology's work on timber pulping for Sarawak (funded by ADAB) and Papua New Guinea (funded by the Commonwealth Fund for Technical Co-operation), the development of a high-protein milk biscuit by CSIRO and Arnott-Brockhoff-Guest Pty Ltd, and the provision of tropical

grass and legume samples and eucalypt seeds to developing countries from the collections of CSIRO.

AUSTRALIAN AID THROUGH MULTILATERAL BODIES

16.4.13 Australia also contributes aid to developing countries indirectly, through its membership of international bodies. In 1977-78 Australia is contributing \$88.2million towards the development assistance activities of bodies such as the World Bank, the Asian Development Bank, the United Nations Development Program and other UN agencies and associated bodies, the Commonwealth Fund for Technical Co-operation and of regional bodies in Asia and the Pacific. A large proportion of such activities could broadly be termed scientific and technological co-operation, although it is impossible to identify the exact proportion. However, it has been estimated that \$7.4million will be applied to R&D programs conducted by multilateral bodies in 1977-78. Of this amount, \$2.7million is a contribution towards the activities of the Consultative Group on International Agricultural Research (CGIAR). This has as its major objective a substantial increase in the production of food in the Third World through the implementation of research programs at the twelve agricultural research centres which operate under its auspices. Another example of a multilateral organisation to which Australia contributes, and which conducts research for developing countries, is the UN World Health Organisation (WHO). WHO will spend about \$10million in 1978 (about 6% of its budget) on health research, as well as conducting extra-budgetary, special training or research programs. WHO also operates a Global Advisory Committee on Medical Research, and an International Cancer Research Agency.

16.4.14 In addition, Australia has committed \$15million to the ASEAN-Australian Economic Co-operation Program. The major activities under the Program thus far have been two applied research projects - one on the development of low-cost, protein-rich food based on soya bean, and the other dealing with the development of improved techniques for food storage, handling and transport. Australia is also a member of the International Atomic Energy Agency's Asian Regional Co-operative Agreement in Nuclear Science and Technology, which provides a framework for co-operative research, development and training through national installations.

TRENDS IN CO-OPERATION WITH DEVELOPING COUNTRIES

16.4.15 At present Australia is devoting a considerable proportion of its aid to the agricultural and public works sectors, both of which involve strong inputs of science and technology. Almost 90% of expenditure on the research components of bilateral projects is in the field of agriculture.

16.4.16 Australia's participation in science-based development assistance has been considered in two reports: 'International Research Assistance Foundation' by a study group headed by Sir John Crawford in 1976; and 'Development Research in Australia: Problems and Prospects', a report to the Minister for Foreign Affairs by Helen Hughes in 1975. The Independent Inquiry into the CSIRO in its report (1977) devoted some attention to development assistance as it affects CSIRO, and recommended that CSIRO should contribute scientific and technical research to foreign aid programs, whether the work is carried out in Australia or abroad. The matter is also under consideration by a group of Government officials, set up to examine implications, for the Commonwealth, of Australia's participation in international science and technology. A common theme in the Hughes and Crawford reports has been the reactive nature of Australian efforts to date (i.e. Australian agencies receive ad hoc proposals and react to them in an ad hoc way) and the need for integration of effort, through the establishment of a co-ordinating body for Australian research for development, with the very successful Canadian International Development Research Centre as a model.

16.4.17 Recently, there have been several improvements in the quality and administration of Australia's aid program; these enable Australia to marshal its resources in a more effective manner and to develop, in concert with recipient governments, more effective programs. Aid to major recipients such as Papua New Guinea, the South Pacific countries, and the ASEAN members, has been placed on a multi-year basis. The project-identification process has been greatly improved and better appraisal techniques and evaluation studies have been introduced. Program planning missions now visit recipient countries regularly and such missions usually include technical experts.

16.4.18 Of particular relevance to the R&D components in the aid program is the recent establishment of the Consultative Committee on Research for Development. The Committee is composed of scientists and administrators of institutions, and senior government officials. Its task is to assist ADAB to develop a more cohesive program of activities, commensurate with Australian capacity and directed to the research priorities of developing countries. The Committee will assist in identifying more systematically than at present, the research needs and problems of developing countries. It will also advise ADAB on particular research projects and programs, and, by providing a direct link with the Australian scientific community, advise on the availability of appropriate Australian expertise. CSIRO has also moved to rationalise and co-ordinate its scientific and technical development assistance activities and is establishing a special unit to act as a focal point for such activities.

16.5 FUNDING

16.5.1 Table 16.1 summarises available information on the 1977-78 levels of expenditure by the Commonwealth Government on civil aspects of

international scientific and technological co-operation. As expenditure on science and technology is not usually separated out from total expenditure on aid projects, or from the total contribution to multilateral organisations, it is difficult to arrive at precise figures for this expenditure. The entries in Table 16.1 for contributions to multilateral organisations must be taken as an over-estimate of scientific and technical content, as they would include a non-scientific component. Nevertheless, Table 16.1 provides an interesting comparison of amounts spent on aid, bilateral agreements, and multilateral organisations.

TABLE 16.1

INTERNATIONAL SCIENTIFIC/TECHNICAL CO-OPERATION
AUSTRALIAN GOVERNMENT EXPENDITURE 1977-78

	\$million
<u>Scientific and Technological Aid</u>	
ADAB Estimate of Cost of Research Component of Bilateral Aid Program	<u>30.8</u>
Contributions to Multilateral aid Organisations -	
United Nations Development Program	5.51
Association of South East Asian Nations (ASEAN)	2.30
Economic and Social Commission for Asia and the Pacific (ESCAP)	0.70
South Pacific Commission	0.95
Commonwealth Fund for Technical Co-operation	1.20
Consultative Group on International Agricultural Research	2.70
World Meteorological Organisation - Voluntary Assistance Program	0.02
International Atomic Energy Agency - Technical Assistance	<u>0.10</u>
	<u>13.48</u>
<u>Bilateral Agreements</u>	
Bilateral Science and Technology Agreements -	
USSR-Australia Science and Technology Agreement	0.13
USA-Australia Agreement for Scientific and Technical Co-operation	0.075
FRG-Australia Science and Technology Agreement	0.02
India-Australia Science and Technology Agreement	0.012
Exchange Arrangement between the Australian Academy of Science and Academia Sinica Peking	<u>0.047</u>
	<u>0.264</u>
Bilateral Arrangements for Co-operative Activities -	
Australia-Japan Foundation	0.5
Australia-America Education Foundation	0.2
Cultural Agreements	<u>1.1</u>
	<u>1.8</u>
Scientific/Technical Component	about 0.18

	\$million
<u>Contributions to Multilateral Organisations</u>	
United Nations Educational, Scientific and Cultural Organisation (UNESCO)	1.48
Food and Agriculture Organisation (FAO)	1.36
International Atomic Energy Agency	0.51
United Nations Environment Program	0.45
World Health Organisation	2.14
World Meteorological Organisation	0.17
International Telecommunications Union	0.56
International Civil Aviation Organisation	0.26
Organisation for Economic Co-operation and Development (OECD)	1.23
International Cancer Research Agency	0.33
Asia-Pacific Telecommunity	0.02
Association for Science Co-operation in Asia	0.02
	<u>8.53</u>

Source: Department of Science.

APPENDIX 16.1

AUSTRALIA'S BILATERAL SCIENCE
AND TECHNOLOGY AGREEMENTS

<u>Partner</u>		<u>Australian Lead Department/ Agency</u>
USA	Signed in 1968 and renewed for a further five years 1973. Australian funds were \$68,000 for 1976-77. Activities include joint symposia and visits by scientists of both countries. No specific areas of co-operation have been designated but the agreement does provide a mechanism for specific purpose inter-agency agreements.	Science
USSR	Signed in 1975. Australian funding in 1976-77 was approximately \$120,000. Co-operation has revolved around group and individual visits. Seven subject areas (plant breeding, entomology and plant protection, radio astronomy, earth sciences, applied geology, textile technology and animal production) have been selected for special emphasis.	Foreign Affairs (with assistance from CSIRO)
India	Signed in 1975. Funding for 1976-77 was \$8,000. Agricultural research, energy and the earth sciences are currently being accorded a high priority.	Science
Federal Republic of Germany	Signed in 1976. Funding for this agreement during 1976-77 was \$15,000. So far there have been reciprocal visits by national delegations. Energy research, marine science and technology and Antarctic research have been chosen as areas of mutual interest. Some collaborative projects are planned.	Science
China	Commenced 1977. Operated by the Australian Academy of Science, with Government funding (\$47,000 in 1977-78). Group and individual visits between Australia and China. No subject areas are chosen for special attention.	

INTERNATIONAL ORGANISATIONS -
A REPRESENTATIVE LIST

		Lead Department/ Agency
1. <u>UNITED NATIONS - Standing Committees of the General Assembly</u>		
	Committee on the Peaceful uses of Outer Space	Science (Foreign Affairs)
2. <u>UNITED NATIONS - Economic and Social Council</u>		
CSTD (1973)	Committee on Science and Technology for Development	Foreign Affairs
ACAST (1963)	Advisory Committee on the Application of Science and Technology to Development	Foreign Affairs
ESCAP (1947)	Economic and Social Commission for Asia and the Pacific	Foreign Affairs
3. <u>UNITED NATIONS - Specialised Agencies and IAEA</u>		
UNESCO	United Nations Educational, Scientific and Cultural Organisation. To contribute to peace and security by promoting collabor- ation among nations through education, science and culture. Includes: World Science Information System, Man and Biosphere (MAB) program, Intergovernment Oceanographic Commission (IOC).	Foreign Affairs; Science; Australian National Com- mission for UNESCO
FAO (1945)	Food and Agriculture Organisation. To promote the common welfare by furthering separate and collective action towards raising the levels of nutrition and standards of living through increased food production and food security.	Foreign Affairs through Primary Industry
WMO (1950)	World Meteorological Organisation. Co- operation and standardisation in meteorology through training, research and information exchange.	Science
IAEA (1957)	International Atomic Energy Agency. To seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world.	Foreign Affairs Australian Atomic Energy Commission

WIPO	World Intellectual Property Organisation. Promotes world-wide protection of intellectual property; deals with legal and administrative aspects of intellectual property; founded on multilateral treaty.	Productivity (Patents Office)
WHO	World Health Organisation.	Health
IMCO	Intergovernmental Maritime Consultative Organisation	Transport
ICAO	International Civil Aviation Organisation	Transport
ITU	International Telecommunication Union	Telecom (Postal and Telecommunications)

4. UNITED NATIONS - Other Bodies

UNCTAD	U.N. Conference on Trade and Development	Overseas Trade
UNEP (1972)	United Nations Environment Program. Promotes international co-operation in the environment field and recommends policies to this end.	Environment, Housing and Community Development (EHCD)
UNDP (1965)	United Nations Development Program.	ADAB (Foreign Affairs)
UNIDO (1967)	U.N. Industrial Development Organisation	Foreign Affairs (Industry and Commerce)

5. OECD

OECD	Organisation for Economic Co-operation and Development	Foreign Affairs
CSTP (1972)	Committees for Scientific and Technological Policy. Investigates the role of science in economic growth and the social implications of scientific and technological innovation.	Science
DAC (1961)	Development Assistance Committee	ADAB (Foreign Affairs)
NEA	Nuclear Energy Agency	Australian Atomic Energy Commision

(1975)	Committee for Energy Policy	National Development
(1970)	Committee on Environment	EHCD
(1961)	Committee on Agriculture and Fisheries	Primary Industry

6. ASSOCIATION FOR SCIENCE CO-OPERATION IN ASIA (ASCA)

- (1970) Exchange information on natural scientific resource functions and research programs; provide advisory services; identify and examine areas of common scientific or technological interest and provide solutions to priority problems on a bilateral or multilateral basis through the resources of existing agencies.

7. COMMONWEALTH OF NATIONS

CSC (1946)	Commonwealth Science Council to provide a forum for discussions between the scientific organisations of the Commonwealth.	Foreign Affairs
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8. OTHERS

CGIAR	Consultative Group on International Agricultural Research	Foreign Affairs (ADAB)
ASCA	Association for Science Co-operation in Asia	Science
	Asia-Pacific Telecommunity	Postal and Telecommunications

ICSU AFFILIATES AND OTHER ASSOCIATIONS
ADHERED TO BY AUSTRALIAN ACADEMY OF SCIENCE

Scientific Committee for Antarctic Research (SCAR)
International Astronomical Union (IAU)
International Union of Biochemistry (IUB)
International Union of Biological Sciences (IUBS)
International Union of Pure and Applied Biophysics (IUPAB)
International Union of Pure and Applied Chemistry (IUPAC)
International Union of Crystallography (IUCr)
Committee on Data for Science and Technology (CODATA)
International Federation of Societies for Electron Microscopy
International Association of Geochemistry and Cosmochemistry
International Mineralogical Association
International Union of Geodesy and Geophysics (IUGG)
Inter Union Commission of Geodynamics (IUCG)
International Union of Geological Sciences (IUGS)
International Geographical Union (IGU)
International Union of the History and Philosophy of Science (IUHPS)
International Federation for Theory of Machines and Mechanisms
International Mathematical Union (IMU)
International Union of Theoretical and Applied Mechanics (IUTAM)
International Union for Nutritional Sciences (IUNS)
Scientific Committee for Oceanic Research (SCOR)
International Commission for Optics
Pacific Science Association
International Union of Pharmacology (IUPHAA)
International Union of Pure and Applied Physics (IUPAP)
International Union of Physiological Sciences (IUPS)
International Union for Quaternary Research
International Union for Radio Science (URSI)
Scientific Committee on Problems of the Environment (SCOPE)
Special Committee on Solar-Terrestrial Physics (SCOSTEP)
Committee on Space Research (COSPAR)

CHAPTER 17

FUNDAMENTAL RESEARCH

Photograph: A section of the Large Magellanic Cloud (the nearest galaxy to our own) taken with the Anglo-Australian Telescope at Siding Spring Observatory. The black object at the lower left is the first extra-galactic supernova remnant to be discovered. The large mushroom cloud (similar in shape to that produced by an atomic explosion on earth) above this object is thought to be produced by shock waves from the explosion interacting with the interstellar medium. Spectra of the small dark areas in the mushroom show that they are probably ultra-high velocity fragments of the exploding star. This photograph is a beautiful example of how the interstellar medium (which originally was only hydrogen and helium) becomes enriched with other elements synthesised inside stars, thus making life possible.

(Photograph courtesy Mt Stromlo Observatory)

CHAPTER 17

FUNDAMENTAL RESEARCH

17.1 INTRODUCTION

17.1.1 Other chapters of this overview concentrate on studies of the application of science and technology to specific areas of Australian economic and social activity; that is, on the applied region of the science-technology continuum [1]. This chapter concentrates upon the more fundamental region of the spectrum and attempts to focus on that particular, if ill-defined, zone variously termed fundamental research, basic research, investigator-initiated research, or curiosity-oriented research.

17.1.2 It must be stressed that this does not purport to be a comprehensive, exhaustive and detailed study of fundamental research in Australia; rather it is a broad view set within an overview of Australian science and technology. Furthermore, a conscious attempt has been made to emphasise those areas of fundamental research not covered in other chapters. While this chapter concentrates on university research, it is recognised that much fundamental research is conducted elsewhere, and indeed virtually every research endeavour will have some component of basic science in it.

17.1.3 ASTEC is currently undertaking a longer-term inquiry into the arrangements for, and levels of funding for, basic research in Australia; this includes an examination of the operation of, and level of funding of, the Australian Research Grants Scheme. It is expected that ASTEC's report will be completed by the end of 1978.

17.2 FINANCIAL SUPPORT OF FUNDAMENTAL RESEARCH IN AUSTRALIA

17.2.1 Fundamental research in Australia is carried out principally in universities and government research laboratories, with the Commonwealth Government providing 93% of the funds. In Project SCORE, Survey and Comparison of Research Expenditures [2], information on fundamental research in the natural sciences is included in the objective 'Advancement of Science', and the expenditure recorded for 1973-74 (excluding the business enterprise sector) was \$129 million. The amount spent by the business enterprise sector on fundamental research over the same period is estimated to be of the order of \$1 million, and the total amount, \$130 million, represents 22% of all expenditure on R&D in the natural sciences in 1973-74.

17.2.2 However, the 'Advancement of Science' objective includes components other than fundamental research. An amount of \$90 million is given for basic research within this objective, and this is a more reliable estimate of the total expenditure on basic or fundamental research. It has not been possible to estimate separate expenditures for the selected areas of fundamental research described in this paper.

17.2.3 Australian expenditure on 'basic' research within different sectors is compared with that of other OECD-member countries in Table 17.1.

TABLE 17.1
COMPARISON OF EXPENDITURES ON BASIC RESEARCH

Country	Year	Expenditure on basic research [a] as a percentage of total expenditure on R&D within different sectors (natural sciences and engineering only)			
		Government	Business Enterprise	Higher Education	Total for all sectors
Australia	1973-74	20.5	9.7[b]	72.8	28.2
France	1975	18.2	4.0	89.3	20.3
West Germany	1975	34.2	4.7	100.0	23.8[c]
Italy	1975	27.0	2.1	41.9	14.1
Japan	1975-76	15.8[d]	5.2	70.9[d]	14.2
Sweden	1975	20.8	1.8	70.0	19.0
United Kingdom	1975-76	20.7	3.3	95.2[e]	16.1
United States	1975	12.0	3.0	61.7	12.9

[a] Basic research as defined by the OECD: 'Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view'.

[b] Figure may include expenditure in the social sciences.

[c] Approximate figure.

[d] Excluding research in the medical sciences.

[e] All research in universities is assumed to be basic research.

Sources : International Survey of the Resources devoted to R&D by OECD member countries; International Statistical Year 1975. OECD, Paris 1977, 1978

: Project SCORE; Research and Development in Australia 1973-74, Australian Government Publishing Service, Canberra, 1976.

17.2.4 Within the higher education sector the total expenditure estimated to be devoted solely to R&D for the 1974 academic year was approximately \$61million. However, in the estimate by Project SCORE a fraction of the expenditure on teaching-and-research activities has been included. In other words, an assessment has been made of the proportion of time that academics spend on research, and an equivalent percentage of their salaries and associated costs has been notionally debited. With this addition, the higher education sector's R&D expenditure rises to \$142 million for the year 1974. Expenditure on R&D in the natural sciences was \$100million, of which \$99million was spent by universities. There is no accurate estimate of the proportion of these funds spent on fundamental research, although in Project SCORE it is reported that basic research accounted for 73% of all research in the natural sciences in the higher education sector. The amount spent by the higher education sector on fundamental research would therefore be of the order of \$60-70million in 1974.

17.2.5 Before 1973 the State Governments contributed directly to the funding of university research, but in that year the Commonwealth Government assumed responsibility for the financial support of universities. Commonwealth Government funds are now allocated to the universities through the Tertiary Education Commission in four broad categories: general recurrent grants, equipment grants, special research grants, and building grants. Special research grants are intended to provide funds to support the general research effort of universities and are, in general, substantially supplemented by each university, and to a degree determined independently by each university, from its general recurrent grant. In allocating special research grants the former Universities Commission stated its view that 'research is an essential activity of a university. Indeed it is the characteristic that most distinguishes universities from other institutions of higher education' [3].

17.2.6 These general university mechanisms allow the possibility of a certain base level of research in every university department. However, what exists in fact is a two-tiered system whereby this base level support can be augmented by additional, competitively-awarded funds. Thus, through the initiative of individuals and groups, the more important and imaginative research projects can grow with support from:

- . grants from other government sources, particularly the Australian Research Grants Committee (ARGC), the National Health and Medical Research Council (NH & MRC), and some 'industry' funds;
- . grants, contracts and donations from private sources; and
- . fellowships and scholarships provided by governments, industry, and private sources such as trust funds and endowments.

17.2.7 The ARGC recommends grants in all disciplines other than the medical and dental sciences, and to research workers in all institutions other than government laboratories and the Schools of the Institute of Advanced Studies at the Australian National University. In practice, almost all recipients of ARGC grants are university staff. The criteria used by

the Committee are the excellence of the applicant and of the project. These are also the criteria employed by the NH & MRC in its recommendations for grants in the fields of medicine and dentistry. In general, support for research projects is short-term (1-3 years), but successful groups can, and do, re-apply.

17.2.8 The amounts given in grants to the higher education sector for the calendar year 1974 are shown in Table 17.2. These amounts were not necessarily spent in that year.

TABLE 17.2

GRANTS TO THE HIGHER EDUCATION SECTOR, 1974

	<u>\$million</u>
ARGC	6.4
NH & MRC	3.0
Other Commonwealth Government grants	1.6
Grants and scholarships provided by State governments, business enterprises and private, non-profit organisations, 1973-74 (not necessarily for fundamental research only)	7.1

Source: Project SCORE; Research and Development in Australia 1973-74, Australian Government Publishing Service, Canberra, 1976.

17.2.9 Although universities are the major performers of fundamental research in Australia, other organisations whose principal research activities may be described as applied or mission-oriented undertake in addition a certain amount of fundamental research. This serves to provide long-term support for applied research, and to attract and retain highly trained scientists.

17.2.10 Some of the major Commonwealth Government organisations which carry out fundamental research are listed in Table 17.3 below, together with an approximate estimate of the amounts expended on fundamental research in 1973-74. These figures are useful for comparison with other data for 1973-74, the latest year for which Project SCORE data are available.

TABLE 17.3

ESTIMATED EXPENDITURE ON FUNDAMENTAL RESEARCH BY
COMMONWEALTH GOVERNMENT ORGANISATIONS, 1973-74

	<u>\$million</u>
CSIRO	13.9
Bureau of Mineral Resources	1.4
Anglo-Australian Telescope Board	3.1
Antarctic Division, Department of Science	1.6
Australian Atomic Energy Commission	1.3

17.2.11 In addition, some fundamental research is carried out by industrial research establishments, defence establishments, and private, non-profit institutes. Although there is no accurate estimate of the expenditure of these organisations on fundamental research, it is unlikely that the amount spent in 1973-74 exceeded \$5million.

17.3 FUNDAMENTAL RESEARCH IN BROAD FIELDS OF SCIENCE

17.3.1 Data on research expenditures may be found in 'Project SCORE, Research and Development in Australia 1973-74'; of particular relevance are the tables containing data by field of science and type of activity. These should be interpreted with caution bearing in mind, for example, the definitions and classifications employed and the probable variations in interpretation placed on these by respondents.

17.3.2 What follows is a summary of comments from workers in each discipline, in which an attempt is made to assess the status of fundamental research in that discipline. This section should be read in conjunction with the other chapters of this volume as it only includes comments on topics which are not discussed elsewhere. A more rigorous review of each discipline needs to be undertaken before detailed policies and actions are formulated; this review does not purport to provide an adequate basis for deciding upon future research directions and funding policies.

PHYSICAL SCIENCES

17.3.3 Fundamental research undertaken in Australia in the physical sciences (meaning here physics, astronomy and mathematics) extends over a wide spectrum of activities and involves a significant outlay of resources. In certain fields Australia enjoys a high international reputation. As with most research, such successful fields are usually created by the inspiration of individual scientists, and evolving groups of scientists. The originality and effectiveness of this research is not brought about simply by the provision of funds, and conversely there are many instances of well-funded research projects that have yielded little return.

17.3.4 Areas in which Australia's international reputation in the physical sciences is particularly high include the following:

- . astronomy;
- . solid state physics;
- . certain areas of mathematics such as number and group theory;

- . crystallography;
- . spectroscopy (across the whole electromagnetic spectrum); and
- . surface physics and catalysis;

17.3.5 Other areas can be identified in which distinguished work has been accomplished by individuals or small groups; these include fluid dynamics, optics, environmental physics and meteorological physics. Considerable work has also been done in nuclear and plasma physics, but the impact of the local effort has been less significant in these fields of high international expenditure.

17.3.6 Australian research in solid state physics, involving theoretical and experimental investigations of a wide variety of solids, has provided scope for innovation and advances in understanding. The tertiary institutions together with government and industrial laboratories have made important contributions to the study of transport properties, optical properties, mechanical properties, radiation damage, magnetic structures, and many other aspects of the properties of solids. The special properties of the surfaces of solids have also been the subject of important Australian research.

17.3.7 Crystallography utilises techniques involving the diffraction of X-rays, electrons and neutrons. The diffraction equipment is of relatively low cost, and original methods of using these techniques have been developed in Australia and have been used for the solution of challenging new problems. As well, interest has moved recently into the area of structural-analysis of biologically important molecules.

17.3.8 Spectroscopy covers a wide range of techniques, including nuclear magnetic resonance and electron spin resonance. Contributions to the understanding of the basic phenomena have been made in Australia and these developments have been incorporated into instrumentation primarily used for chemical and physical analysis of materials; typical of this effort is the creation of the National Nuclear Magnetic Resonance Centre, which provides an analytical service at an increasingly sophisticated level.

17.3.9 An especially important area of development of spectroscopy is that of atomic absorption spectroscopy, which again provides a means of accurate chemical analysis. This technique was originally developed in Australia and is now widely used throughout the world. It has made a major contribution to chemical analysis.

17.3.10 Australian research on the physics of solids and on catalysis has a historical basis in the need for understanding the practical and theoretical problems associated with friction, lubrication and bearings. From this there emerged work on the behaviour of metals under stress and on the reactivity of surfaces, and fundamental studies of the physics and chemistry of the surfaces of solids. More recent work has concentrated on the properties, behaviour and utilisation of industrially important metals, alloys, ceramics and refractories.

17.3.11 Australian physicists have also made contributions to the study of nuclear physics and plasma physics, although the scope of experimental work has been severely limited by the facilities available. However, there is continuing interest and expertise in theoretical nuclear physics, which, in some institutions, is of international standing, and there are plans to expand Australian work in the theory of plasmas.

17.3.12 Australia's unique position as a scientifically advanced nation located in the southern hemisphere, with its access to objects such as the Milky Way Galaxy, the nearest external galaxy, and the nearest radio galaxy, has contributed to its high ranking amongst the world's leading astronomical nations. However, even more important is the fact that since the Second World War Australia has been one of the foremost two or three nations of the world to pioneer and develop the new science of radio astronomy, from an absolute standpoint rather than that of geographically privileged position. Radio astronomy has caused a revolution in astronomy that has put the subject in the forefront of the physical sciences during the second half of the twentieth century.

17.3.13 Australian astronomers are engaged in studies in most areas of astronomy and in the development of astronomical instrumentation. While radio astronomy and optical astronomy are the major fields of interest, Australian astronomers are also active in infrared astronomy, cosmic ray astronomy, and theoretical studies. Much of the research is carried out in collaboration with overseas scientists. The extent of co-operation in research programs and the shared use of facilities is a feature of fundamental research in this field of science.

17.3.14 Fundamental research in the mathematical sciences (pure and applied mathematics, statistics) in Australia is extensive and diverse. In certain field such as statistics, algebra, fluid mechanics and mathematical physics, the country has a high standing.

17.3.15 Australian research in pure mathematics has increased markedly during the past decade. Areas of particular strength in algebra are group theory, number theory, category theory and combinatorics, the first two being well established. In general, the field of analysis, which encompasses about one-half of international research in pure mathematics, is not strong. Productive mathematicians working in areas such as harmonic analysis, functional analysis, and ordinary and partial differential equations are somewhat scattered throughout the country. Australia is clearly weak in the general field of geometry and topology, and some of the currently significant areas of modern mathematics such as algebraic geometry, differential geometry and differential topology, together with related areas of algebra and analysis, are barely represented.

17.3.16 Research in applied mathematics, while still largely conforming to the classical British mould and emphasising continuum mechanics, in particular fluid mechanics, has, in recent years, diversified considerably to embrace applications to a wide range of scientific areas such as the modelling of biological systems, biophysics and colloid physics. Little use is made of modern, pure-mathematical ideas, and the mutually fruitful co-operation between pure and applied mathematicians (often professional engineers) that exists to some extent in North America and continental

Europe is lacking. It is possible that research in applied mathematics is also disadvantaged by the dispersal of talented researchers throughout the country and by insufficient input from local situations and problems.

17.3.17 Probability and statistics are areas of research in which Australia enjoys a high international reputation. The fields covered by local research workers include: probability theory, applied probability, stochastic processes, statistical theory, applied statistics, medical statistics and computational statistics. Areas requiring further encouragement include data analysis, time series analysis, multivariate analysis and medical statistics, while the areas of sample-survey theory and robust modelling require almost a complete development.

17.3.18 Finally, research in computational methods in the mathematical sciences is very limited in Australia with the areas of data analysis and numerical analysis requiring special attention. In particular, research and expertise in numerical analysis is almost wholly limited to one centre.

CHEMICAL SCIENCES

17.3.19 It is possible to identify three major areas of research in chemistry in which Australia has a wide, international reputation. These are:

- the study of the chemistry of natural products including porphyrins, alkaloids, terpenes, proteins and carbohydrates.

- structural and synthetic inorganic chemistry with special reference to the use of x-ray diffraction studies to define chemical structures, and the properties and chemical reactions of co-ordination and organometallic compounds.

- the field of spectroscopic methods applied to chemistry especially in fields such as atomic absorption spectroscopy, microwave spectroscopy and nuclear magnetic resonance spectroscopy.

17.3.20 Although there are research workers in Australia who individually have international reputations in other areas of chemistry, the three major areas above have the highest proportion of internationally-known chemical researchers.

17.3.21 It may be noted that the list of areas which may be considered of greatest merit in chemistry within Australia does not include any of the more traditional areas usually denoted by the term physical chemistry. This is an area which is of prime importance to technical development of industry and unfortunately is one area which has had only limited growth within Australia.

17.3.22 This no doubt reflects the international interest in the different branches of chemistry. There are fashions in scientific research as in other human endeavours and the classical areas of physical chemistry, for example thermodynamics, kinetics, and electrochemistry, have tended to

become less prominent in the international scene. Interest appears to have been concentrated in the last two decades on the preparation of large numbers of new classes of chemical compounds and the application of physio-chemical techniques to the study of their structures. Nevertheless there are new areas in the field of catalysis and in gas-solid reactions, in the understanding of biochemical processes, and in conversion of solar to electrical energy, which are potentially of great applied as well as fundamental significance.

EARTH SCIENCES

17.3.23 Although activity in the earth sciences is widespread throughout Australia, fundamental research of the quality that merits world recognition is concentrated in only a few centres. The broad areas in which recognition has been achieved include mineralogy of igneous rocks, palaeontology, petrology and isotope geochemistry. Fundamental research in the fluid earth sciences, including meteorology, hydrology and oceanography, is discussed in other chapters.

17.3.24 Australia continues to play a leading role in geomagnetic studies linked with the dating of rocks, and related to studies of the ocean floor and to continental movements. Apart from this palaeogeographical research, bearing on the fundamental problem of the mechanism of large scale crustal movements, palaeomagnetic research is contributing to the equally fundamental problem of the creation and secular variation of the earth's magnetic field. The study of sedimentary basins is an essential adjunct to this research, but one not yet receiving sufficient attention.

17.3.25 Australia has contributed substantially to developments in geochemistry. In particular, studies of the trace element composition and of the behaviour of mineral and rock types under extremes of pressure and temperature have resulted in the development of analogue techniques, and more recently in the development of new equipment such as diamond anvils and heating by laser beams. A model, the pyrolite model, most generally used in discussions of the composition of the earth, was devised in Australia.

17.3.26 Phase transformation in silicates under extremes of temperature and pressure has been correlated with discontinuities in seismic velocity. Australia is particularly well suited for such studies because, although not itself especially seismically active, there are such zones to the north of the continent, enabling the whole of the distance range relevant to the study of the properties of the earth's interior to be well covered. In these studies the seismic array, operated in central Australia in conjunction with the United Kingdom, plays an important role.

17.3.27 Australian research has made major contributions to the understanding of plate tectonics, on both the macro- and micro-scale. The increasing use of plate-tectonic concepts in exploration illustrates well the point that applied science is carried out in the context of the basic science of the day. Aeromagnetic mapping and isotopic age determinations, combined with the increasing understanding of Archean magmatogenesis, form

the background against which the nickel prospects of Western Australia have been discovered.

17.3.28 Geochemical studies of samples of lunar rocks, in which several Australian scientists have participated, have led to new understanding of the early history of the solar system and of the earth. Australian researchers continue to be at the forefront of the synthesis and interpretation of lunar data and two of the current models of the lunar composition, as well as a new theory of the formation of the moon from the earth, originated in Australia.

17.3.29 Research areas which are not well developed in Australia include:

- . the mechanism of large scale plate movements, leading to an understanding of fundamental earth-shaping processes and the occurrence of earthquakes. Active participation is essential in such relevant programs as lunar, laser ranging; satellite, laser ranging; and very long base-line interferometry;
- . marine geology and geophysics programs commensurate with Australia's geographical and geological location, and with the area of its zone of exclusive rights;
- . mapping of surface rocks; interaction between centres in universities and the Bureau of Mineral Resources and State geological surveys should be encouraged as it is essential to Australian research in basic earth science;
- . geology of sedimentary basins and fossil fuels; and
- . geomorphology.

BIOLOGICAL SCIENCES

17.3.30 Australia's major contributions to fundamental research in botany have been in the field of plant physiology. Pioneering work was carried out in this country on the importance of minor elements in the nutrition of agricultural plants, and plant nutrition is still an important area of research. In more recent years research into the ionic relations of plant cells, respiration, nitrogen fixation, and translocation has been of international significance. Australian workers are amongst world leaders in photosynthesis research; the discovery of the alternative photosynthetic pathway was made in this country. Another important area of fundamental research deals with the water relations of agricultural, and native, arid-zone plants.

17.3.31 The principal weakness in botanical research in Australia is the lack of any continuing, systematic study of the biology of the native flora. Although a few individual species, or particular groups, have received attention, the native flora represents a largely unresearched resource of potentially valuable genetic and physiologic diversity. In particular, little

is known of the biology of native timber species or of plants found in the northern half of the continent.

17.3.32 Fundamental research in plant pathology and genetics has declined, although these are of particular relevance to Australia and were formerly important areas of research.

17.3.33 Although there are Australian zoologists working on a wide range of topics, fundamental research in zoology is poorly developed in this country except in the field of animal physiology. An original impetus for physiological studies was the need to understand the biology of agricultural livestock, and studies of the nutrition, metabolism and reproduction of cattle and sheep continue to be an important area of research, and one in which Australia has made major contributions. Attention has also been focused on the environmental physiology of native and exotic animals, and the work of Australian zoologists on reproductive physiology and endocrinology, and on water metabolism and thermoregulation, is of high international standing. There has been a recent increase in fundamental research in palaeontology, particularly in studies of marsupials, and pressure from archaeologists requiring interpretations of fauna associated with early man has resulted in work on mammalian and avian osteology.

17.3.34 The need for increased support in zoology has been summarised in the 1973-75 Report of the Australian Research Grants Committee [4]:

Other areas of weakness include invertebrate and lower vertebrate physiology, invertebrate and vertebrate systematics including parasitological projects. In view of the richness, diversity and uniqueness of the Australian continental fauna, the disparity between the low level of activity in these areas and the strength evident in the disciplines of microbiology, biochemistry and higher vertebrate physiology is a matter of concern to the Committee, since it reflects a serious lack of development in the zoological sciences in Australian universities and museums.

17.3.35 Especially marked is the lack of knowledge of the unique Australian fauna, a fauna which is of particular interest to scientists in all parts of the world. Despite a well-established research effort in taxonomy, it has been estimated that 50% of the Australian fauna remains undiscovered and undescribed (the great majority of undescribed species are insects); moreover, fundamental research in the ecology of species which are known is, with few exceptions, almost entirely lacking. World scientific opinion holds that work on the Australian fauna is not only of very great interest, but is urgently needed in view of the increasing environmental stress placed on the fauna.

17.3.36 In biochemistry, as in other fields, success and international recognition depends on the ability and drive of gifted individuals. Strengths in Australian biochemistry centre on:

immunology; molecular aspects are within the discipline of biochemistry;

- . organelle biogenesis; specifically the biogenesis of mitochondria and chloroplasts;
- . bioenergetics; the transduction of energy in biological systems;
- . protein chemistry;
- . enzymology; particularly enzyme kinetics, enzyme mechanisms and physical biochemistry;
- . molecular biology; including the biochemistry of chromosomal structure and function, protein synthesis and virology; and
- . biochemical genetics including bacterial metabolism.

17.3.37 Fundamental research in biochemistry is very much an international activity of the affluent nations and there are few areas which are more suited for study in Australia than for study elsewhere. The identification of gaps in biochemistry in Australia is somewhat arbitrary and could be misleading in the absence of a systematic consideration of the many subdivisions of the subject that exist around the world.

17.3.38 With that proviso, some further work may be required on the x-ray crystallography of macromolecules, on environmental biochemistry, and on plant biochemistry (excepting research on photosynthesis and nitrogen-fixation). Some strength in plant biochemistry would be appropriate for Australia in view of the importance of plant products. Two areas of plant biochemistry which could be strengthened are the biochemistry of plant hormones and the biochemistry of stress and disease in plants. The metabolism of inorganic nitrogen and sulphur compounds in micro-organisms and in plants is important in the Australian context because of the deficiencies of these elements in Australian soils.

17.3.39 Basic research in medicine (which includes basic medical biochemistry) is poorly supported in Australia. Much of the medical research is clinically oriented and aimed at particular medical problems. There is a good case for increased support for medical biochemistry and for multi-disciplinary work involving biochemists, physiologists, pathologists, cell biologists, and other specialists.

17.3.40 In microbiology it is possible to identify several areas in which Australian research figures prominently in world-wide recognition. In some cases the topics of study overlap with areas of biochemistry, genetics or medicine. This is inevitable in the biological sciences. Areas of strength include:

- . industrial microbiology; food processing, fermentation technology, single-cell protein and microbial energy production;
- . environmental microbiology; microbiology of wastes, pollution and waste water control;
- . veterinary microbiology; diseases of Australian fauna and of animals used for agriculture;

- medical microbiology; vaccines, antibiotics, pathogenicity mechanisms, tropical diseases, viral chemotherapy and others.

17.3.41 Microbiological topics of a general nature which may merit further encouragement include the study of non-pathogenic commensals and symbionts of man, and bacterial genetics and genetic engineering. The latter impinge on other areas of research, namely fermentation technology, nitrogen fixation, and problems of antibiotic resistance.

17.3.42 Of the traditional areas of genetics research those in which Australia has particular strength include:

- quantitative and population genetics, which has led to significant advances in breeding (for example crop varieties) and which is well represented in Australian research. Research in this area is at the forefront of world effort;
- chromosome genetics and cytogenetics; of particular interest and relevance is the cyto-evolution of Australian native flora. There is a need for more research of this type not only to establish the genetic structure of the flora but also as a means of studying the interaction of genotype and environment;
- studies of *Drosophila* and other standards, which have proceeded from extensive work in fundamental cytogenetics to more modern molecular cytogenetics. This movement, and the range of species studied, is gathering pace; and
- recently, studies of marsupial, mammalian, and human genetics.

Genetics research in Australia is concentrated in three or four centres. In the main it continues work begun by the top-ranking geneticists who have come to Australia, particularly from the United Kingdom.

17.3.43 It is clear that for Australian genetics, and biology in general, significant movement is represented by the coming together of biochemistry and genetics researchers, and the increasing awareness of the overseas trend towards the dominance of molecular genetics. Surprisingly, however, the impact of the theory and techniques of molecular biology on general biology (and genetics in particular) is slow to affect the directions of fundamental research in Australia. The early, inhibitive complexity of the techniques, and the cost of specialised equipment required for molecular biology, no longer hinder. Simpler techniques have developed with the science, and the instrumentation of other disciplines, especially chemistry, have been adapted to these techniques: for example, ultraviolet, infrared and nuclear magnetic resonance spectrometers; ultracentrifuges; and chromatographic techniques such as high-pressure, liquid chromatography. It is essential for the continuing health of Australian research in genetics that encouragement of research programs be directed to overcoming this lag.

17.3.44 Immunology is a branch of science in which Australia has attained high international recognition. Interest by the public, and by young scientists, has sustained the high standards of research work;

particularly is this so in medical areas of immunology (organ transplantation for example). Major research activities include:

- . lymphocyte origins, subgroups, functional interactions and the genetic control of interactions;
- . microbial (especially bacterial and viral) immunity;
- . application of immunology to clinical medicine;
- . genetics of antigens of human leucocytes.

Research areas in which weakness is discernible and which may merit development in Australia are studies of immunoglobulin synthesis, structure and genetics; allergy; and immunogenetics in general in view of the major importance of genetics to both humoral and cellular immunity. Immunological research related to matters of tropical health also merits expansion. Such research includes microbial immunity, especially in the area of parasitism, and immunological aspects of undernutrition.

17.3.45 Some fields of physiological research are very strong in Australia. Prominent amongst these are:

- . neurophysiology and neuropharmacology, including the physiology of vision;
- . endocrinology, with special reference to research on sex hormones, endocrinological aspects of control of blood pressure and hormones affecting salt and water balance;
- . cardiovascular and respiratory physiology, including regulation of blood pressure, influence of lipids on blood vessels and embryological aspects of heart and lung functioning.

Australia's prominence in the field of physiology is recognised through the involvement of many Australians in the relevant international scientific unions and societies, and the holding within Australia of prominent symposia and congresses.

ENGINEERING SCIENCES

17.3.46 Under this heading we include, somewhat arbitrarily, the bulk of university research in engineering, computer science, metallurgy, surveying and architecture. Much of this activity has been the subject of comment in other chapters of the report, so the discussion here is briefer than that in other sections.

17.3.47 Research in engineering sciences in universities developed later than research in the pure sciences, and there is still a marked unevenness in the level of research endeavour in the different universities. Much of the activity in universities is devoted to solving particular problems of engineering practice rather than to engineering research, and of course it

is quite proper that this should be the case. The question of what the balance should be nation-wide and even within particular institutions is one which requires further study.

17.3.48 The area of greatest research concentration is unquestionably fluid dynamics, a fruitful area which ranges from sophisticated laboratory and theoretical studies to large scale field investigations. The popularity of work in this area may be in part a response to the situation that the traditional analytical problems of engineering have been significantly resolved by computer-based numerical methods. However, these advances have only served to show up the deficiencies which exist in the definition of properties of materials. There is thus a need now, especially in civil and mechanical engineering, for applications studies under short- and long-term loading, and for a move towards physics, chemistry and mathematics in order to replace the traditional empiricism of engineering practice by a fundamental understanding.

17.3.49 In electrical engineering, there is a need for activity in the field of computer hardware, where there is little successful work. The area of device design and integrated circuits is also an area of low activity, though what activity does go on is often of good quality; the problem is that the technologies tend to lie only with difficulty within Australia's industrial capacity and the capacity of universities to provide the research infrastructure. Research in computer science is another area of major weakness, and this is of concern to ASTEC.

17.3.50 Chemical engineering has some active centres, mostly emphasising process technology; this momentum should be sustained. There are also a number of active groups in other specialised scientific fields, for example, control theory, machining, physical metallurgy, photogrammetry, and soil mechanics. Very little research involves environmental studies.

17.3.51 It must again be stressed that this analysis is exemplary and not exhaustive, and individual engineering scientists of excellence are active in a variety of other fields. Furthermore, it is recognised that (as mentioned above) there is a considerable overlap between the research described in this section and that dealt with in many of the other chapters.

17.4 COMMENTS ON CURRENT ARRANGEMENTS FOR THE SUPPORT OF FUNDAMENTAL RESEARCH

17.4.1 The current arrangements for the support of fundamental research - block Government allocations to the Tertiary Education Commission and bodies such as the Australian Atomic Energy Commission and CSIRO, specific project support by granting bodies such as the Australian Research Grants Committee (ARGC) and the National Health and Medical Research Council (NH & MRC), and support from special-interest groups such as the Australian Wool Corporation and the Radio Research Board - are well-established and generally well-accepted by the research

community. This is particularly so for the ARGC - NH & MRC system which combines peer review with support for excellence. The activities of the NH & MRC are discussed in the chapter on Health. Here, attention is drawn to the important role of the ARGC in the support of fundamental research in Australia.

THE HISTORY OF THE AUSTRALIAN RESEARCH GRANTS COMMITTEE

17.4.2 It may be useful to recount briefly the history and purpose of the ARGC. A committee of ten members was set up in April-May 1965, and an amount of \$4million was provided for the support of high-quality research. Project selection was on the basis of the excellence of the project and the investigator, rather than on the investigator's status. Also, no heed was to be taken of any particular distribution of funds between universities, States or disciplines. The projects were to be based in Australia at other than government authorities. Social sciences and humanities were included; while these do not fall directly within ASTEC's ambit, they are an important part of ARGC's responsibility (for 1977, 18% of grants, 12% of funds). On the other hand, projects in the medical and dental sciences (covered by the NH & MRC) and in some aspects of education (covered by the Education Research and Development Committee) are not funded. Over the years, the increasing workload has necessitated an increase in the number of Committee members from the original ten to the present eighteen.

17.4.3 For comparison with ARGC funds (\$9.15 million), NH & MRC funds in 1976-77 were \$9.10million, and Education Research and Developmental Committee funds, \$1.10million.

17.4.4 The history of ARGC funding is summarised in Appendix 17.1. The announced annual grants (given in column 2) are converted, in column 3 and in all subsequent money columns, into December 1976 dollars, described as 'real' dollars. Column 4 reduces the real-dollar figures to a relative base 1974 = 100, 1974 having been the high point in ARGC funding. Column 5 lists the number of grants, and column 6 (column 5 divided by column 3) the average 'real' grant. The submission from the ARGC pointed out that, over a period in which there has been a formidable expansion in higher education, there has also been an increase in the size of the research community which looks to ARGC for support. A simple measure of the size of this community was thought to be the number of university staff-members of the grade of lecturer and above (column 7) [5]. Dividing the total 'real' grant (column 3) by this number of staff-members (column 7) gave a quantity called, for want of a better term, the 'average theoretically available real grant' (column 8). This was expressed on the base 1974 = 100 in column 9. On this basis there has been a reduction in funding per staff-member. Throughout the committee's life, funds granted for a particular year have been supplemented to allow for statutory salary increases, and to a lesser extent for increases in costs of non-salary items.

17.4.5 Good research can be cut back overnight by reducing funds; it cannot be quickly expanded, for research is not amenable to crash

programs. An increase in research of any kind, and in ARGC-sponsored research in particular, requires funds to be steadily and predictably increased. This applies no less to funding for special projects than to mainstream ARGC projects.

17.4.6 It is interesting to set ARGC's funds against the total funds for universities, and the total funds for research in universities. The last two decades have seen a dramatic increase in total government (Commonwealth and State) expenditure on education, and on higher education in particular. For example [6], between 1966-67 and 1974-75 the proportion of all government expenditure which was directed to education rose from 14.8% to 23.2% (or in terms of the Gross Domestic Product, from 3.2% of GDP to 5.7%). The universities' share of the GDP rose in the same period from 0.68% to 0.95%, while expenditure in the college of advanced education (CAE) and technical and further education (TAFE) sectors rose even more substantially (0.41% to 1.21%). In dollar terms, this growth meant that, in 1977, the total funds available to State universities were of the order of \$500million. In 1974, the funds expended on research in State universities, as a proportion of their total government funds, amounted to approximately 26% [7], compared with 31% in 1969. If the 1974 proportion is maintained in 1977, this means that some \$120million is attributable to research expenditure in state universities in that year.

17.4.7 However, these general funds for research (that is, other than ARGC funds), are mainly attributable to staff salaries and to infrastructure. Funds for the particular, individual project are frequently very small, too small in many cases to permit effective progress. It is because ARGC operates within an existing infrastructure that its allocations are exceptionally cost-effective.

GAPS IN CURRENT FUNDING ARRANGEMENTS

17.4.8 ARGC's ability to fund a particular project is limited to about \$100,000 a year (or perhaps \$150,000 in a particular year). Indeed, the only two projects which it has consistently supported at such a level (the Sydney University radioastronomy observatories at Fleurs and at Molonglo) are of long standing, and ARGC has been unable, for want of funds, to enter into any other commitment of such a magnitude. The problem of funding expensive facilities is addressed in Section 4.4 of Volume 1A.

17.4.9 The standards of research in the United States of America, and lately in other countries, depend heavily on the participation of young scientists already trained to PhD level. Instructively, the Institute of Advanced Studies at the Australian National University absorbed this lesson at the outset, and about 50% of its staff posts are of this kind. Following the 1975 cut in the ARGC budget, the number of postdoctoral workers supported by grants from the Committee fell from 120 to 66. Tenure is given for up to three years and hence the average number of new fellowships now awarded annually in each discipline, for all Australia, is about 3. This situation compares most unfavourably with that in, for example, Canada, particularly as there are few alternative sources of funds for such purposes in Australia. ASTEC believes that it is necessary

to fund first-quality postdoctoral fellows, and that this would be a less expensive and more effective method of promoting fundamental research than using additional PhD students, some of whom may be of second-class quality.

17.4.10 . There is also a need for modest funds (to be awarded on a basis which lays less stress on the proven record of the investigator) to encourage new, younger, research workers ('starter grants'). Finally, there is a need to establish a system within the ARGC whereby an outstanding individual or group, with a first-class program, can be supported for a guaranteed period of a few years. All these suggestions will require additional funds, and if additional funds are provided to the ARGC the relative priorities of any new endeavours should be assessed by the ARGC and funded accordingly.

17.4.11 Few scientists prosper in isolation. Most need inputs in the form of ideas, problems, new information, advice and the regard of peers. The North American-European scientific community is able to achieve a high level of internal communication relatively easily. Australian scientific communication on the other hand suffers from certain difficulties that must be accepted as unavoidable; a small community, widely scattered; internal air travel costs that have lately become very high, an exceptionally high cost if one is to meet colleagues in any other scientifically developed country; and remoteness from manufacturers and suppliers of high-technology scientific equipment. These factors are worth comment, in historical and in present perspective. The wide dispersal of Australian universities meant, in practice, minimal contact until the early 1960's. Conditions then permitted internal travel and the development of local scientific meetings, on a worthwhile scale. Unfortunately Sydney-Adelaide by air, for example, is now as costly as a charter flight from North America to Europe, and internal Australian contacts may well become less frequent.

17.4.12 Overseas travel presents a picture of a different kind. Scientists at Australian universities rarely have adequate local funds to permit their attendance at meetings overseas; but overseas conference organisers have been glad to have Australian representatives and have often been able to offer worthwhile help to one, or a few, Australian participants. The matter of funds for conference travel is a vexed one and the ARGC is regularly importuned to assist. It has had to set its face against almost all proposals of this kind, the exception being when it is asked for travel funds to enable a researcher to use facilities unavailable in Australia. These disabilities in respect of overseas travel are offset by sabbatical or study leave. The financial costs to the individual, especially if his family accompanies him, are often severe. For all that, the Australian sabbatical convention is an important link in the maintenance of scientific contacts and awareness. Study leave provisions are being examined by the Tertiary Education Commission.

17.4.13 Universities and CSIRO are sufficiently akin, and have in the past been sufficiently close together geographically, to have evolved in recent years a more healthy, less one-sided relationship than existed previously. However, formal arrangements for sharing resources have never developed to the extent for which many had hoped. The reason

would appear to be that the 'sharing' which is advocated is, too often, seen by each proponent as a transfer of resources. Future CSIRO-university initiatives might have to be funded by both parties if they are to break through present attitudes and practices.

17.4.14 Much that has been said of CSIRO and universities applies also to other government science, such as defence, communications, specialised agencies, and also State government instrumentalities or departments. A few university workers stumble into contact with these branches of government and some do, it is true, have more solid connections (atomic energy, agriculture); but, by and large, the university sector is ignorant of the problems and opportunities which are on offer in these areas. This is unfortunate, for the scale of government applied technology, transport, power generation, water supply, etc., is vast and the opportunities for profitable interaction are considerable. Attempts to establish useful working contacts with industry have been going on for years, again with few evident results. Science in North America and Western Europe, on the other hand, is strongly stimulated by the problems and economic opportunities of the world outside the laboratory, and by the readiness of applied scientists (and capital) to support ideas. There is no reason why the talents of Australian university scientists should not be as readily enticed by applied problems as by the challenges of discipline-oriented research. Industrial contract research would be one initiative, and this is discussed in Chapter 6 of Volume 1A. Other initiatives may be required to bring to industry a knowledge of, and access to, the high level technology which universities possess. It is instructive to reflect, for example, that very few industrial laboratories possess the instrumentation, among which nuclear magnetic resonance and mass spectrometry are pre-eminent, with which, and in terms of which, chemistry students are now trained.

NOTES AND REFERENCES

1. A science-technology continuum is an attractive and useful analogy; however, it can be argued, equally convincingly, that the two evolve in parallel according to a relationship that is complex and non-linear. Cross-linked parallel threads might be a more accurate analogy.
2. Project SCORE: Research and Development in Australia 1973-74, Australian Government Publishing Service, Canberra, 1976.
3. Australian Universities Commission: Fifth Report, May 1972, paragraph 10.1.
4. Australian Research Grants Committee: Report 1973-75, page 13.
5. Colleges of Advanced Education, while they have access to ARGC, seek and receive only a very small fraction of ARGC funds. However, of university staff-members, 12% look primarily to NH & MRC and so ARGC covers exclusively only 88%. But the staff figures quoted exclude tutors and senior tutors, who are an increasingly visible element in ARGC's operations. On the whole, the time series shown in column 9 has the virtue of simplicity; insofar as it shows a decline it certainly does not exaggerate it.
6. G.A. Withers, 'Relative trends in Government Expenditure in Education'. Appended Paper B6, Submission by the Australian National University to the Committee of Inquiry into Education and Training.
7. Funds expended for research from 'Project SCORE: Research and Development in Australia 1973-74', after deducting the total cost of the Research Schools at the Australian National University.

APPENDIX 17.1

AUSTRALIAN RESEARCH GRANTS COMMITTEE, FUNDING, 1965-1977

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	
	Announced	December	Grant in real terms(b)		Average	Average Total	Average theoretically available		
Year(a)	Grant	1976 prices	Relative	Number	Grant	Number of	real grant per staff-member(c)		
	\$million	\$million	(1974=100)	of Grants	December	Professional	December	Relative	
					1976 prices	University	1976	(1974=100)	
					(\$thousand)	Staff	prices (\$)		
	1965	3.985	9.159	78	406	22.6	4019	2279	136
	1966	3.429	8.001	68	555	14.4	4399	1819	109
(d)	1967	3.084	7.045	60	573	12.3	4707	1497	90
	1968	2.958	6.546	56	572	11.4	5008	1307	78
	1969	4.100	8.755	75	665	13.2	5426	1614	97
(d)	1970	4.201	8.188	70	709	11.6	5646	1450	87
	1971	5.255	9.552	81	787	12.1	5979	1598	96
	1972	5.757	9.995	85	840	11.9	6245	1600	96
(d)	1973	6.602	10.200	87	889	11.5	6602	1545	92
	1974	8.623	11.744	100	1,031	11.4	7026	1672	100
	1975	7.091	8.032	68	1,062	7.6	7608	1056	63
	1976	9.150	9.153	78	1,167	7.8	7957	1150	69

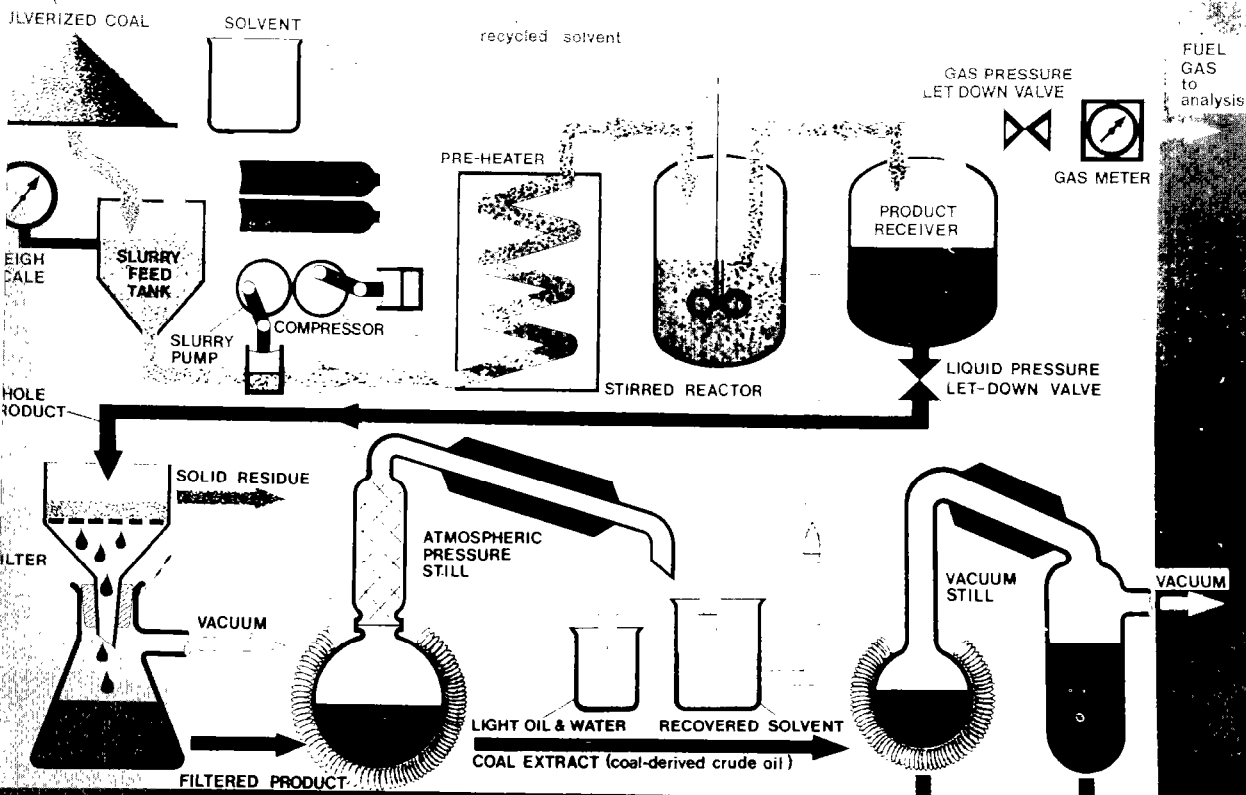
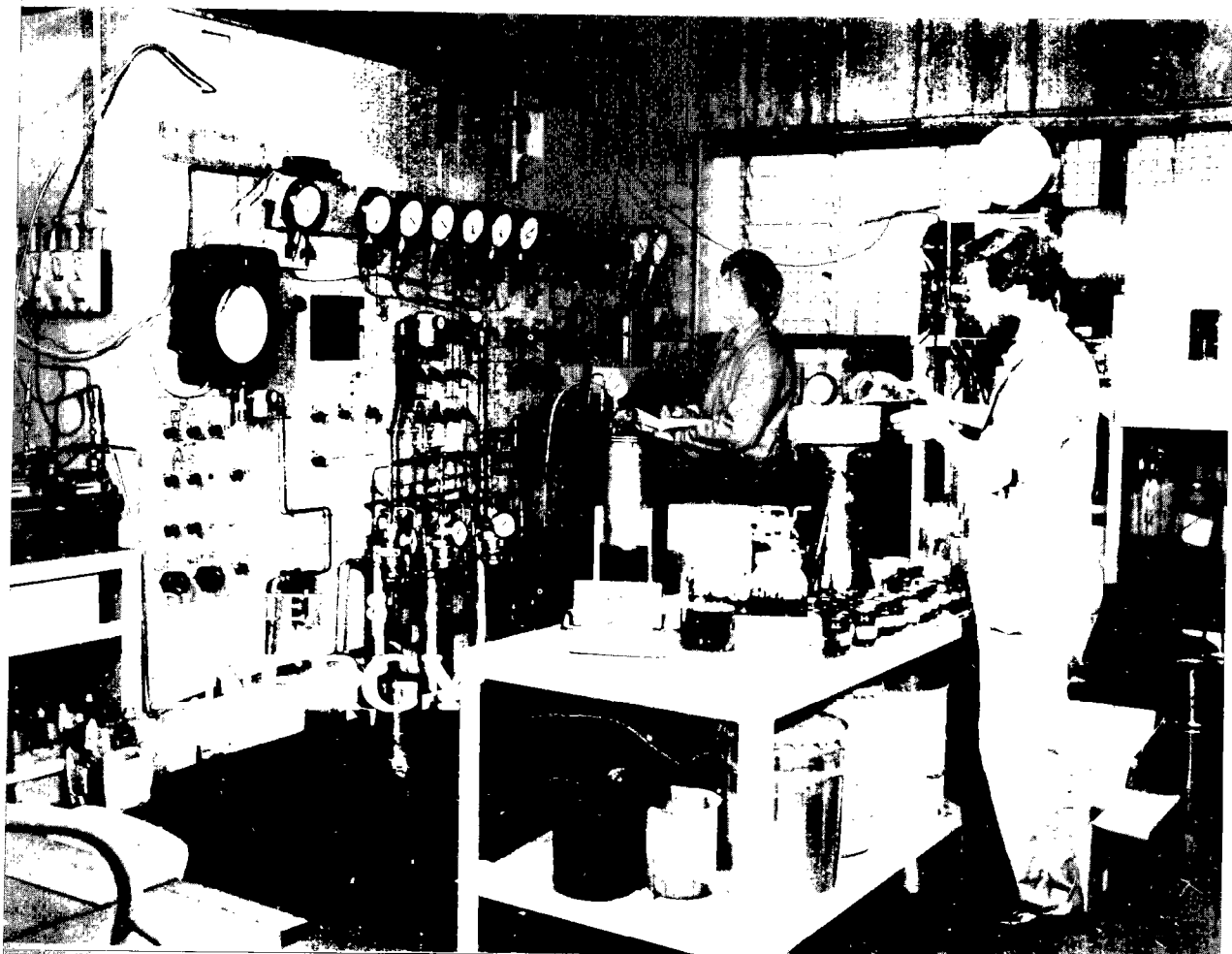
(a) Year of application for funds which are available in the following year.

(b) The grants are actually made in the following calendar year.

(c) Column (3) divided by Column (7).

(d) Triennial funding.

Source: The Australian Research Grants Committee submission to ASTEC.



Photograph: A number of laboratories in Australia are investigating oil-from-coal conversion processes. The photograph of the Australian Coal Industry Research Laboratories' Continuous Reactor Unit shows the front control panel on the explosion-proof steel chamber housing high-pressure coal hydrogenation equipment. Product slurry from the unit is being filtered to remove unconverted solid residue. The inset shows the flow diagram for the system.

(Photograph courtesy Australian Coal Industry Research Laboratories).

CHAPTER 18

ENERGY

18.1 DEFINITION OF AREA COVERED

18.1.1 In this chapter the field of energy research and development is classified as follows:

Energy sources and their processing

- . Coal
 - extraction, assessment, preparation, carbonisation, combustion and gas cleaning, and conversion.
- . Crude petroleum and petroleum products
- . Hydro-energy
- . Nuclear energy
 - uranium exploration, extraction and beneficiation; uranium enrichment; fission reactors; fusion science.
- . Solar energy
 - direct heating, cooling systems, design of thermal systems, storage.
 - solar-electrical conversion, thermal conversion, photovoltaic conversion, thermoelectric conversion, wind conversion.
 - production of fuels.

Energy conversion, distribution and use:

- . Electricity generation, transmission and use
- . Conservation of energy
- . Pipelines (including liquid, gas, slurry)

18.1.2 Mining in general forms the topic of another chapter of this Report, but in this chapter those aspects of mining which are directly related to the supply of an energy resource are considered. Similarly, some agricultural and forestry aspects are included in discussing the production of ethanol. Fuel for transport is of primary importance in Australia and it is therefore inevitable that some overlap occurs with the chapter on Transport. Notes on studies of environmental factors are also included in some sections.

18.2 ORGANISATION AND FUNDING

18.2.1 It is not possible to consider the organisation and funding of energy research and development in isolation from the whole energy organisational structure. It is clear that this structure has the complexities of an unco-ordinated evolution, but recent changes are leading to rational departures from the historical basis. The organisational structure is discussed below.

FUNDING

18.2.2 In the absence of a major, definitive survey, no accurate statement can be made of the funding of energy R&D in Australia. The subdivisions used in the 1973-74 Project SCORE (Survey and Comparisons of Research Expenditures) [1] are too broad to allow a reliable figure to be extracted, and the more definitive 1976-77 data are not yet available. Limited surveys undertaken by the Department of National Development, and extrapolation of these data, have led the Department to estimate that Commonwealth Government funding for non-nuclear energy research and development in 1976-77 was in excess of \$10million [2]. The dissection of the expenditure by the Australian Atomic Energy Commission given later in this section shows that, of the 1976-77 expenditure of \$22.4million, \$9.12million can reliably be classified as being for energy R&D, giving a total Commonwealth funding of about \$20million in 1976-77 for energy R&D.

18.2.3 State governments, both directly and through their statutory authorities, contribute substantial sums to energy R&D. The total sum involved is estimated as approximately \$10 million.

18.2.4 Many Australian industrial companies spend considerable sums for research and development work performed in other countries. Some contribute directly to the general maintenance of the R&D effort of overseas principals. However, some companies have active energy R&D programs in Australia and, on the basis of the very limited data available, it appears that this could involve an expenditure of about \$5million.

18.2.5 These estimates, Commonwealth Government \$20million, State governments \$10million, private industry \$5million, lead to the conclusion that the 1976-77 level of funding for energy R&D was of the order of \$35million. Combined Commonwealth and State government funding represents about \$2.20 per capita which may be compared with \$12.90 per capita in the USA and \$6.35 per capita in the United Kingdom.

18.2.6 The Commonwealth Government has recently announced that in 1978-79 funds will be provided to encourage an expansion in energy R&D. The 1978-79 budget provides \$4million for energy R&D grants in 1978-79, and the Government is prepared to commit a further \$5million against expenditure in future years. Additionally, about \$6million, representing

accruals and reserves in the Coal Research Trust Account, will be available for coal research. These funds are in addition to those provided to government authorities such as the CSIRO and the Australian Atomic Energy Commission.

COMMONWEALTH GOVERNMENT

18.2.7 The Commonwealth Minister with primary responsibility for energy matters is the Minister for National Development. The portfolio includes responsibility for:

- . the Department of National Development;
- . the National Energy Advisory Committee;
- . the National Energy Research Development and Demonstration Council;
- . the Australian Atomic Energy Commission (other than commercial development and marketing of uranium);
- . the Pipeline Authority; and
- . the Snowy Mountains Hydro-Electric Authority.

18.2.8 The Department of National Development provides, inter alia, advice to the Minister on national energy policy, including planning and research into coal, oil and gas, uranium, solar and other sources of energy. It also undertakes, through the Bureau of Mineral Resources, Geology and Geophysics, geological, geophysical and geodetic surveying, produces geological and topographic maps, and carries out resource assessment. A National Energy Office has now been established in this Department; it is responsible for the development and review of national energy policy and research, and for developing national energy initiatives.

18.2.9 The National Energy Advisory Committee (NEAC), originally established as an interim committee in 1977, advises the Minister on all matters relating to national energy policy. To date, five reports have been published by NEAC dealing with energy conservation, energy resources, energy research and development, motor spirit, and electric vehicles.

18.2.10 The National Energy Research Development and Demonstration Council (NERDDC) was established in May 1978 to advise the Minister on the co-ordination of the national effort in energy research, development and demonstration. It will also advise on the disbursement of the funds from the coal research levy imposed by the Coal Research Assistance Act 1977, and additional funds which the Commonwealth Government has provided for the expansion of energy R&D.

18.2.11 The Australian Atomic Energy Commission (AAEC) was established in 1953 under the Atomic Energy Act 1953. The Commission has a Chairman, Deputy Chairman and three other members. It is a self-contained, autonomous body which reports direct to the Minister for National Development. The principal roles of the Commission are to promote the search for, and mining and treatment of, uranium in Australia, to purchase and sell uranium on behalf of the Commonwealth, to develop practical uses for, and to sell, products of atomic energy, to undertake research and development, to promote training and research in universities and elsewhere, and to collect and distribute information on uranium and atomic energy. The Commission operates a Research Establishment at Lucas Heights (see 18.4.3). There is close collaboration with international organisations such as the International Atomic Energy Agency and the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development, and with many national laboratories in the USA, Canada and Europe, through bilateral agreements.

18.2.12 The Pipeline Authority was established under the Pipeline Authority Act 1973. It is charged, inter alia, with the construction, maintenance and operation of pipelines for the conveyance of natural gas and other hydrocarbons.

18.2.13 The Snowy Mountains Hydro-Electric Authority was established by Act of Parliament in 1949 to provide the necessary works in the Snowy Mountains area for the generation of electricity and its distribution to the States of NSW and Victoria and to the Australian Capital Territory, and for the diversion of water inland for irrigation purposes. The operation and maintenance of these works for the control of water and production of electricity, and the allocation of loads to generating stations is directed and controlled by the Snowy Mountains Council.

18.2.14 The Joint Coal Board is constituted under the Coal Industry Act 1946 of the Commonwealth Parliament and the Coal Industry Act 1946 of New South Wales Parliament. It has broad responsibilities in relation to the production and use of coal in NSW, and funds R&D to assist in the discharge of these responsibilities.

18.2.15 Reference should also be made to the Australian Minerals and Energy Council (AMEC). This Council is chaired by the Minister for Trade and Resources with the understanding that the Minister for National Development will preside over the discussion of energy items on the agenda. Membership of the Council consists of Commonwealth and State Ministers concerned with minerals and energy. Because of the nature of constitutional responsibilities for energy matters, the co-ordinating role of AMEC is of vital importance in the formulation of effective energy policy in Australia. AMEC is advised by an Advisory Committee consisting of the senior officers of the Commonwealth and State departments whose Ministers are on AMEC.

18.2.16 The Minister for Science is responsible for CSIRO. The operation and organisation of CSIRO has recently been the subject of study by an

Independent Inquiry [3]. In carrying out its scientific research role relating to Australian primary and secondary industries, CSIRO has established considerable expertise and facilities for pursuing energy R&D programs. Using a conservative definition of energy research, the total expenditure on these programs, details of which are given in 18.4.1, was \$7.82million in 1976-77.

18.2.17 Also under the Minister for Science is the Australian Research Grants Committee (ARGC) which assesses, and advises the Minister on, research proposals submitted by university and other non-government institutions for support under the ARGC scheme. The Committee's assessment is based solely on scientific merit. In 1977 ARGC supported 15 projects on energy to a total of \$166,000 and over 30 energy projects, with a total grant of \$450,000, have been approved for 1978.

18.2.18 The Minister for Science also has in his portfolio the Department of Science, within which is the Bureau of Meteorology which maintains a network of meteorological recording stations. A proportion of these stations measure solar radiation and other data required for the design of systems to collect and use solar energy to meet a given load in different geographic locations in Australia.

18.2.19 On 1 July 1978, the Northern Territory Electricity Commission was established as a statutory authority with powers and responsibilities similar to those in the States. Previously, public electricity supply was the responsibility of the then Minister for the Northern Territory through his Department, and the Department of Construction as its agent. Plant in mining towns and on cattle stations is privately owned and operated. All plant in the Territory is either oil-fired, steam plant or diesel plant, which results in high generating costs. This has encouraged extensive use of solar collectors for water heating.

18.2.20 Other Commonwealth Government ministers with direct responsibilities in the energy field are:

- . the Minister for Construction, with responsibility for the Experimental Building Station which undertakes research into building technology, and the Building Research and Development Advisory Committee which advises the Department of Construction on building research and development priorities. Recently a major area of activity has related to the use of energy in buildings, particular attention being directed to energy wastage;
- . the Minister for Defence, supported by the Department of Defence, which oversees the Defence Science and Technology Organisation embracing the Australian Defence Scientific Service, the major defence laboratories (see 18.4.5) and the planning and administration of research programs;
- . the Minister for Environment, Housing and Community Development, who maintains within his Department an interest in

resource and energy conservation and energy use in the built environment;

the Minister for Post and Telecommunications has in his portfolio Telecom Australia, whose Engineering Department has a long history of innovation in the generation of electricity for unattended communications equipment in remote areas;

the Minister for Productivity, with responsibility for the Australian Industrial Research and Development Incentives Board which administers the Industrial R&D Incentives Act 1976 providing funds for R&D projects, including some relating to energy, in industrial laboratories;

the Minister for Trade and Resources, who carries the Commonwealth responsibility for the commercial development and marketing of minerals, including uranium and coal; and

the Minister for Transport, with very wide responsibilities in the transport field.

STATE GOVERNMENTS

18.2.21 All States have established advisory and/or executive bodies in the field of energy. In Western Australia the State Energy Commission has jurisdiction over electricity generation, distribution and sales and natural gas distribution and sales. In other States roles in these areas are shared between a wide range of organisations including State authorities, local Government authorities and private companies. In Victoria, and South Australia and to some extent in NSW, coal mines are generally owned and operated by the State. In all States the petroleum industry is privately owned and operated though setting of the price of petroleum products is a State responsibility.

18.2.22 In each State a government department, usually termed the Department of Minerals and Energy or Department of Mines and Energy, has responsibility for energy planning. This body has responsibility for implementing policies and programs determined by the government and provides detailed advice to the relevant Minister.

18.2.23 State government departments, commissions and committees relating to research and development are important in the formulation of energy policy. Proposals brought by State Ministers to the Australian Minerals and Energy Council, from which national policies will evolve, derive largely from the recommendations of the State commissions and committees. Accordingly the nature, terms of reference and current activity of a selection of the bodies in each State are summarised here.

Western Australia

18.2.24 The State Energy Commission of Western Australia was formed by Acts Amendment No. 25 of the Western Australian State Parliament in 1975. The Commission comprises the Commissioner as Chairman, two Associate Commissioners and two non-voting Assistant Commissioners. The powers and duties of the Commission embrace all aspects of the present and future supply of primary and secondary energy in the State; these include exploration, evaluation and exploitation of indigenous energy resources; generation, distribution and sale of electricity; energy research, development and training; and specification of standards.

18.2.25 The operations of the Commission are administered by the Management Group headed by the Commissioner and the two Assistant Commissioners. The State Energy Commission of Western Australia is the only statutory commission in any state in Australia with full responsibility for coal, electricity and gas supply. The Commission's expenditure on energy research and development is of the order of \$300,000 p.a. and involves the equivalent of four full-time professional staff. Some of the work is contracted to other research organisations. Primary areas of R&D relate to solar energy, distribution and use of electricity and natural gas, the assessment of coals, and a long-term program of study of the possible use of nuclear energy for producing electricity.

18.2.26 The Commission is advised by a broadly based State Energy Advisory Council of Western Australia, established under Section 14 of the State Energy Commission Act, which meets at least 10 times per year. The Council also advises the Minister for Fuel and Energy.

18.2.27 The Solar Energy Research Institute of Western Australia was established by the Solar Energy Research Act, 1977 of the Western Australian State Parliament. It is administered by a Board of three directors of whom the Chairman is an Assistant Commissioner of the State Energy Commission, but it is formally separate from the Commission. The staff envisaged, for the immediate future, is one full-time executive officer only, supplemented by staff seconded from the Commission for special purposes. Although the Act allows the Institute to establish its own research facilities and staff, at present its function of encouraging, co-ordinating, funding and monitoring of solar energy research in Western Australia is performed through entering into joint partnerships with other groups to prosecute specific projects of short to medium term significance to the State. Negotiations are in progress with five major groups, including three from overseas, and it is anticipated that the initial government funding of \$250,000 for the half-year to June 1978 will be more than doubled by the partners in the programs. A formal link with the United States Electric Power Research Institute on solar energy matters has also been established.

South Australia

18.2.28 The SA Department of Mines was reconstituted in December 1977 as the SA Department of Mines and Energy under the jurisdiction of the

Minister of Mines and Energy of the South Australian Government. The Department now includes an Energy Branch, with five professional staff to advise the Minister on all matters relating to energy. In addition, a rationalisation of the various committees in the energy area has been proposed. The Department of Mines and Energy carries out exploration and resource assessment, administers the granting of leases and advises the Minister on the terms under which production tenements should be granted. The research activity of the Department is mainly contracted to the Australian Mineral Development Laboratories (Amdel) (see 18.4.10) and totals about \$550,000 p.a.

18.2.29 The Electricity Trust of South Australia (ETSA) is administered by a Board which is responsible to the Government for the operation of the Trust. It replaced the original Electricity Commission and incorporated the private electricity-supply companies. The functions of the Trust include the generation, transmission, distribution and sale of electricity and of electrical appliances but extend also to exploration, examination and, when appropriate, development of coal resources throughout the State. The Trust operates the only major coal mine in the State at Leigh Creek. Most research is contracted to universities and commercial laboratories in Australia and some is contracted overseas. In-house research is limited to maintaining watching briefs on a range of topics of potential interest to the Trust, including nuclear power generation, and to the solution of current operating problems. The equivalent professional staff involvement in this work would total about 20 man-years per annum. The total expenditure on R&D is of the order of \$0.5million p.a.

18.2.30 Although the South Australian Gas Company (SAGASCO) is privately owned and operated, it has close links with various Government authorities and committees. SAGASCO maintains an active testing and research laboratory and participates in the work of the Australian Gas Association in developing appliance codes, installation codes and pipeline codes, which are closely observed by the industry.

18.2.31 The State Energy Research Advisory Committee of South Australia (SENRAAC) was appointed by the South Australian Cabinet, on the advice of the Minister of Mines and Energy, to administer the distribution of research funds for work relating to energy, especially alternative energy sources, either within South Australia, or which has special relevance to South Australia. An initial sum of \$250,000 was made available by the South Australian Government for the 1977-78 financial year.

18.2.32 In addition SENRAAC is to consult with similar bodies created by the Commonwealth Government and other State governments. The Committee has representatives from the ETSA, SAGASCO, the Transport, Planning, Mines and Energy, and Economic Development authorities, from industry and from the two universities in the State. Although some fundamental, long-term projects have been funded by the Committee, accent has been placed on development and demonstration projects which show promise of either contributing usefully to the supply of energy in the State, or leading to energy-related products which could be manufactured in South Australia in the relatively near future.

18.2.33 Also in South Australia, a Solar Energy Sub-Committee of the Law Reform Committee is investigating legal matters relating to the collection and use of solar energy, including wind energy and associated energy storage media. This Committee reports to the Attorney-General.

Victoria

18.2.34 In Victoria, the Ministry of Fuel and Power and the Mines Department were amalgamated to form the Department of Minerals and Energy on 1 September, 1977, under enabling legislation passed by the Victorian Parliament in December 1976. The two existing statutory authorities, namely the Gas and Fuel Corporation and the State Electricity Commission of Victoria, continue unchanged but are now responsible direct to the Minister of Minerals and Energy.

18.2.35 The Gas and Fuel Corporation was established in 1950 as a statutory authority and has grown progressively since then through government purchase and amalgamation of the various gas companies in the State. Privately held shares in the Corporation still exist but government ownership has now reached 70%. The Corporation distributes and markets both natural and town gas throughout the State, markets and services gas appliances, markets insulation materials through its Gascor Division, runs an Energy Management Centre to provide information to industrial and commercial consumers on the efficient use of energy, manufactures and markets active carbon, and maintains a substantial research laboratory employing 31 professionals.

18.2.36 The State Electricity Commission of Victoria (SECV) is responsible for the generation, distribution and sale of electricity throughout the State. The Commission contributes, through the Electricity Supply Association of Australia, to the research programs supported by the Electrical Research Board (ERB), is responsible for the Herman Research Laboratory, which is the only major research laboratory operated by an electricity authority in Australia, and carries out extensive research and development throughout its various Divisions. The total expenditure on this work in 1976-77 was \$2.4million, including \$0.3million for research contracted by the Victorian Brown Coal Research and Development Committee (see 18.2.37), and involved about 38 full-time-equivalent professional staff. The SECV has a specific charter to mine coal in a defined area of the Latrobe Valley and in some other places for electric power generation and for the manufacture of briquettes. Apart from a few small operations by private companies, all other brown coal deposits are held in reserve by the Victorian Government, although the Mines (Amendment) Act 1975 empowers the Minister for Minerals and Energy to grant exploration licences and mining leases to companies and individuals.

18.2.37 In 1975 State Cabinet established the Victorian Brown Coal Research and Development Committee to advise the Minister for Minerals and Energy on, and to co-ordinate research and development programs relating to, the use of brown coal for purposes other than power generation. Representatives of the Department of Minerals and Energy, the SECV, the Gas and Fuel Corporation and the Commonwealth Department of

National Development and five non-governmental experts with special knowledge in the area are members of the 11-man committee. A new research laboratory has been proposed in the Latrobe Valley to investigate the petrography and other characteristics of brown coal; this work is at present contracted to the Herman Research Laboratory. Links have been established with other countries to facilitate the exchange of scientific and technological information, while oil companies and other industries interested in investigating the conversion of coal to oil have been invited to participate in the Government's brown coal assessment program. The Government intends to legislate for a new statutory body to be responsible for carrying out the Government's policies in respect of the conversion of the State's brown coal resources for purposes other than those previously or currently provided by the SECV and the Gas and Fuel Corporation.

18.2.38 A Joint Select Committee on Conservation of Energy Resources was established under the Joint Select Committee (Conservation of Energy Resources) Act 1976. The Committee of eight members, drawn from both Houses of Parliament, is charged to inquire into, and report on, all aspects of energy conservation in Victoria.

18.2.39 The Victorian Solar Energy Research Committee was appointed by Cabinet in 1977 to review all solar energy research being carried out in Australia, to advise how best to support promising lines of research and to act as the official Victorian Government body on solar energy matters for purposes of liaison and publicity. The Committee reports to the Minister for Minerals and Energy.

Tasmania

18.2.40 The Hydro-electric Commission of Tasmania (HEC) was established under the Hydro-electric Commission Act 1944. The Commission has statutory responsibilities for generation, distribution and sale of electric power, and for related construction works. Responsibility extends to all means of generating electric power although most plant is hydroelectric with, at present, only the Bell Bay (2 x 120 MW oil-fired) thermal sets as standby plant. The Commission maintains its own electrical, civil and hydraulic engineering research laboratories and has participated actively with CSIRO on cloud-seeding experiments to which it contributed approximately \$200,000 in 1971. Studies relating to the environmental impact of hydro-electric works are contracted out, mainly to universities. The major current study of this type is a \$300,000 p.a. study of the effects of the Lower Gordon River scheme on all forms of life in the area. The Commission shares with the Department of Mines the responsibility of advising the Minister of Minerals, Resources and Energy on matters relating to the work of the Australian Minerals and Energy Council.

18.2.41 The Tasmanian State Energy Advisory Committee has recently been established to broaden the scope of advice available to the Minister and to consult directly with similar bodies in other States.

New South Wales

18.2.42 The Energy Authority of New South Wales is a statutory body established by the New South Wales Parliament in November 1976. The functions of the authority are: to carry out investigations and planning relating to the location and distribution, conservation and utilisation of energy and energy resources; to assist and advise the Minister; and to acquire and utilise energy and energy resources or operations. The Authority provides funds for specific, energy R&D projects both directly and through the Electrical Research Board (see 18.2.55). The Authority works closely with the Electricity Commission of New South Wales and maintains close contact with the Australian Gas Light Company, which is the major supplier of gas in NSW, and the other 20 gas companies in the State, over which it has some regulatory control. In times of prescribed emergency, the Authority has full control over all prescribed energy resources and supplies.

18.2.43 The Electricity Commission of New South Wales (ECNSW) is responsible for the generation and transmission of electricity throughout the State and for bulk sales to 39 customers of whom 35 are local government distribution and marketing authorities. The operations and borrowings of the local government authorities are overseen by the Electricity Authority of New South Wales which also licences electricians and establishes safety standards. The Electricity Authority is staffed by personnel from ECNSW although it operates under a separate Act. All bulk electricity is supplied at a uniform tariff throughout the State. The Commission is one of the largest miners of black coal in Australia; it owns four mining companies and has a substantial export market for coal. The three areas of major research activity are in electricity generation, control and transmission; coal mining, assessment and utilisation; and hydraulic research especially related to the design of cooling ponds and cooling water reticulation systems for large power plant. As the Commission does not maintain its own research laboratory, the first of these areas is contracted out mainly through the Electrical Research Board, the second mainly to the Australian Coal Industry Research Laboratories and CSIRO, and the third mainly to the Water Research Laboratory of the University of New South Wales. The total funds allocated in this manner, including administrative overheads, amount to about \$1million per year, but it is estimated that at least an equivalent sum is spent on R&D work within the operating divisions of the Commission.

Queensland

18.2.44 The Queensland Energy Resources Advisory Council was established by the Queensland Cabinet in November 1966 and reconstituted on 1 January 1978. The Council has broad terms of reference which may be summarised as advising the Minister of Minerals, Mines and Energy on optimising the use of Queensland's energy resources.

18.2.45 The Queensland Electricity Generating Board (QEGB) has recently been formed under the Electricity Act, 1976, as a statutory authority through a reconstruction of the responsibilities for generation

and new transmission of electric power in the State. It controls the power stations and main transmission lines and supplies power to seven separate, autonomous Boards which retain responsibility for distribution and sales within their respective areas.

18.2.46 Overall co-ordination, planning and funding of projects within the State, and monitoring of the budgets of all component boards, is the responsibility of the State Electricity Commission of Queensland (SECQ). The Commission also negotiates with the various coal authorities on the supply, distribution and price of steaming coal for electricity generation, and with the sugar industry on the purchase of the small, intermittent excess output from bagasse-fired power-generating plant in the sugar mills.

18.2.47 Energy R&D by the electricity supply industry in Queensland is co-ordinated by the Queensland Electric Authorities Research Committee, which is chaired by the Electricity Commissioner. This Committee co-ordinates the special projects funded at universities, colleges of advanced education and with consultants by the Commission. Research funding exceeds \$200,000 p.a.

18.2.48 The Queensland Coal Board oversees all matters relating to the extraction, distribution, utilisation and export of the State's coal resources, collaborates where possible with the Joint Coal Board, and works closely with both the Queensland Department of Mines, which allocates exploration licences and mining leases, and with the Commonwealth. Queensland differs markedly from other States in that the Queensland Government and its statutory authorities are not directly involved in the mining of coal.

TERTIARY EDUCATION INSTITUTIONS

18.2.49 Funding for energy R&D in universities and colleges is derived from a variety of sources, with the bulk of the funds coming from the Commonwealth Government, through its general funding of universities and through grants, particularly those provided on the advice of the Australian Research Grants Committee (ARGC). Much small scale, or initial study, work is supported by grants from research funds established by some institutions; the funds are generally very limited. The guidelines of the ARGC specifically exclude the granting of funds for development projects. Hence energy projects supported from this source are mostly of a fundamental nature, and tend to offer prospects of application in the long-term only. ARGC funding for energy research projects varied between \$62,000 and \$29,000 during the period 1971-76 but in 1977 rose to \$166,000 (15 projects) and to \$447,000 (over 20 projects) in 1978. The National Coal Research Advisory Committee also allocated \$156,000 to universities in 1977-78. (The functions of this Committee have now been assumed by the National Energy Research Development and Demonstration Council.)

18.2.50 Some State Governments have contributed substantially to university programs of energy research and funds are also received from the Electrical Research Board, the Australian Institute of Nuclear Science and Engineering, semi-government authorities, industrial research associations and industry. However, these grants are overshadowed by the funding of \$5million promised (of which \$3.5million has been received) to the University of Sydney from Prince Nawaf of Saudi Arabia for research and development of a high-temperature solar collector and associated systems.

ACADEMIC RESEARCH ASSOCIATIONS

18.2.51 The Australian Institute of Nuclear Science and Engineering (AINSE) was established with the aim of assisting universities and other academic bodies in research and training activities related to the nuclear field, and to make the reactor and other special facilities at the AAEC Research Establishment at Lucas Heights available for use by staff and students of academic organisations. Membership of the Institute consists of the Australian Atomic Energy Commission and 17 Australian universities. Approximately one-half of the total annual membership subscription of AINSE, which exceeds \$200,000, is provided by the Australian Atomic Energy Commission and the other half is subscribed jointly by the universities. In addition, the Commonwealth Government provided a contribution of about \$250,000 in 1977, which was increased to \$300,000 in 1978, for research and training. In 1977 the total AINSE budget was approximately \$500,000. The distribution of grants between the various sectors varies from year to year. In 1976, grants of the order of \$100,000 were allocated for 86 projects of which approximately \$70,000 was for 45 projects related to nuclear energy, the uranium fuel cycle or associated materials problems. Six postgraduate research students and six postdoctoral fellows were also supported. In 1978 the funds allocated were increased by approximately one-half and included a major component of grants for research related to nuclear fusion. Support is provided for delegates to attend the regular conferences at Lucas Heights on topics of interest to AINSE.

18.2.52 Since its foundation, AINSE has adopted a liberal interpretation of its guidelines which require projects to be related to nuclear science or engineering. Valuable early support to work in rather wider areas has been provided to assist groups working in these areas to become firmly enough established to attract funds from the Australian Research Grants Committee or other bodies.

INDUSTRIAL RESEARCH ASSOCIATIONS

18.2.53 Industrial research associations of various types have provided support and co-ordination of R&D activity both to companies which would otherwise be unable to finance wholly their own R&D and to those with

established research laboratories, staff and programs. Associations which maintain their own laboratories are classified here as Consultant Organisations and are discussed below in 18.4.9 to 18.4.12.

18.2.54 The Australian Mineral Industries Research Association Limited (AMIRA) has 44 companies as members and 20 as associate members. Many of the associate members are subsidiaries of, or otherwise affiliated with, member companies. The administrative costs of the Association are met from overhead charges on all contracts negotiated. Many of the projects are undertaken by contract with the Australian Mineral Development Laboratories (Amdel) (see 18.4.10). Results of contracted research are available only to those companies contributing to the particular contract and may not be published without their consent for an agreed period. Three current projects with a total annual expenditure of approximately \$150,000 relate directly to energy and components of three other smaller projects could be classified as energy R&D. It is typical for between 10 and 15 sponsoring companies to share the cost of each project and receive regular reports on progress.

18.2.55 The Electrical Research Board (ERB) was established in 1945 as a voluntary group to bring government, industry, CSIRO and the universities together in electrical engineering research. The research funds administered by the ERB come from a basic contribution by each of the electricity generating authorities of \$100 for each million dollars of revenue, and by each of the distribution authorities of between \$30 and \$50 per million dollars of revenue as agreed through the Electricity Supply Association of Australia. There are also special grants from member authorities for specific projects. All authorities contribute to the basic grants. The basic grant is disbursed by ERB to maintain a general interest in electrical power engineering in the universities and to ensure continuity of funding of both basic facilities and basic research programs. It has been used over the years to establish geographically distributed centres of concentration for particular areas of research. The special grants for specific projects tend also to be expended in the centres of concentration. This funding arrangement appears to be very cost effective as the centres of concentration also attract substantial research grants from other sources such as the Australian Research Grants Committee. Total grants and contracts administered by ERB each year are of the order of \$220,000, of which about 30% is for special projects.

18.2.56 The Australian Coal Utilisation Research Association (TACURA) was founded originally to encourage participation, by users of coal, coke or coal gas, in the research program of the Australian Coal Industry Research Laboratories (see 18.4.9) the major funding of which was then by the producers of coal through the Australian Coal Association.

18.2.57 The Australian Gas Association (AGA) is a voluntary association of members from gas utilities and from gas equipment manufacturers together with associate members engaged in a wide range of activities associated with the gas industry. International contact is maintained through membership of the International Gas Union and Australia is currently represented on the Union's governing body.

18.2.58 Several professional associations in Australia have been active in providing advice on energy R&D and energy policy in general. In particular, the Institution of Engineers Australia, and the Australian Institute of Energy have been devoting considerable attention to energy.

18.3 POLICIES AND AGREEMENTS

18.3.1 Under the Australian Constitution, energy production and utilisation is one of the responsibilities which remain with the States. However, federal powers in relation to international and interstate trade and commerce, taxation, loan raising, foreign investment and trading of financial corporations formed within Australia give the Commonwealth Government considerable scope to influence decisions on matters involving energy.

18.3.2 Examples of this at present include the influence of excise taxes, export levies on coal, export controls, control of the price of indigenous oil, taxation concessions to certain energy industries, foreign investment regulation, and the level of and conditions governing State grants. While the Commonwealth's responsibility established under the Seas and Submerged Lands Act 1973, gives it the right to control resources in offshore areas, the Petroleum (Submerged Lands) Act 1967 established joint Commonwealth/State control over offshore petroleum.

18.3.3 The main Government references to energy policy are included in the 1977-78 Budget speech by the Treasurer in August 1977 [4], the Prime Ministerial Statement and the Statement by the then Minister for National Resources at the time of the announcement of the policy on the mining and export of uranium in August 1977 [5], and a Ministerial Statement to Parliament by the then Minister for National Resources in November 1977 [6].

18.3.4 The 1977-78 Budget [4] included a levy of five cents per tonne on coal mined in Australia, to finance coal research. The Coal Research Assistance Act 1977 (No. 135) established the Coal Research Trust Account into which are paid levy monies derived from coal as collected by the Tariff Division of the Department of Business and Consumer Affairs, and agreed contributions, of an equivalent value, in cases where the coal is mined by State Governments. This arrangement circumvents possible constitutional difficulties where a State is the coal miner.

18.3.5 The taxation incentives for mining ventures introduced in the 1977-78 Budget have the effect of helping the generation of the large cash flows required for a development of the scale of that planned on the North West Shelf, where a substantial delay will exist before a return is realised on the investment.

18.3.6 Marked differences of opinion exist in the community regarding the mining and export of uranium but out of the debate on the question

have emerged several important energy policy statements unrelated to uranium. The Government decision, stated on 25 August 1977 [5], is that some mining and export of uranium should proceed within strictly determined guidelines, and that 'part of the increased revenues which the Government will derive from uranium development will be used in substantial additional funding of solar energy research as part of our National Energy Program'.

18.3.7 The then Minister for National Resources in his Statement on uranium [5] referred to the recommendations by the Ranger Inquiry that

a National Energy Policy should be developed and reviewed regularly; that steps should be taken to institute full and energetic research programs into liquid fuels and energy sources other than fossil fuels and nuclear fission; and that a program of energy conservation be instituted nationally

and stated that 'the Government accepts these recommendations'.

18.3.8 The then Minister for National Resources' Statement to Parliament [6] on 7 November 1977 summarised the more important aspects of the Government's developing energy policy and listed six policy targets. These are:

- . to move crude oil prices in the direction of international levels;
- . the average growth of energy consumption, particularly of liquid fuels, to be restrained;
- . the highest degree of self-sufficiency in liquid fuels broadly consistent with economic utilisation of energy resources [be achieved];
- . economic oil and gas reserves be developed;
- . to encourage individual major energy projects to meet overseas demand for energy minerals....; and that
- . energy research and development be substantially increased.

18.3.9 The 1978-79 Budget saw the achievement of the first of the above energy policy objectives with the announcement that in future consumers would pay prices for petroleum products which take into account the replacement value of crude oil consumed in Australia. In a Press Statement of 12 September 1978 the Minister for National Development also outlined progress being made by the Government in relation to the other objectives.

18.3.10 Additional funds provided by the Commonwealth Government for energy R&D are detailed in 18.2.6. Expenditure of these funds will be approved by the Minister for National Development on the advice of the

National Energy Research Development and Demonstration Council. This Council will also advise the Minister on co-ordination of the national effort for energy research, development and demonstration.

18.3.11 In March 1978 the Australian Minerals and Energy Council agreed to initiate a National Energy Conservation Program, with strong emphasis on oil. At its August meeting the Council endorsed proposals put forward by its Consultative Committee on energy conservation which included:

- . an initial consultancy study for research and planning of a national energy publicity campaign;
- . energy conservation measures which could be readily implemented by governments for their own organisations and establishments; and
- . energy conservation in transport, buildings and housing.

The present Budget includes provisions of \$50,000 for preliminary research and planning for a national energy conservation publicity campaign. The Council has agreed that this publicity would represent the main activity in the first stage of the co-ordinated National Energy Conservation Program.

18.4 DESCRIPTION OF ESTABLISHMENTS

COMMONWEALTH GOVERNMENT LABORATORIES

18.4.1 CSIRO has 37 research divisions and 6 smaller research units responsible to the Executive. Twenty of these divisions and units were involved in 76 energy-related R&D projects with a total expenditure, including overheads, of \$7.82million in 1976-77. This information updates that provided in the CSIRO Annual Report [7]. The expenditure can be subdivided as follows into specific energy areas: Resource assessment and prospection, \$0.78million; coal, \$3.37million; nuclear energy, \$0.08million; solar energy, \$1.20million; organic matter and wastes, \$0.63million; wind energy, \$0.11million; electricity carriers, \$0.06million; utilisation and conservation of energy, \$1.10million; and energy studies, \$0.48million. These expenditures are estimated to increase to a total of \$9.00million for 1977-78.

18.4.2 CSIRO Divisions which have active programs related to energy are:

- . Applied Geomechanics; improvements in the efficiency and safety of underground and open cut coal mining;

- . Applied Organic Chemistry; fuel, conversion and storage of solar energy;
- . Atmospheric Physics; solar radiation and prediction.
- . Building Research; energy conservation in buildings and transport;
- . Chemical Technology; low energy chemical processes, biosynthetic technology;
- . Environmental Mechanics; wind flow studies;
- . Food Research; waste conversion to methane;
- . Fuel Geoscience Unit; coal and oil resource characterisations;
- . Horticultural Research; solar energy;
- . Land Use Research; urban energy use and the atmospheric environment;
- . Materials Science; catalysts for fuel conversion;
- . Mathematics and Statistics; wind flow modelling;
- . Mechanical Engineering; solar water and air heating, low energy dehumidification and cooling, heat recovery systems, transport energy economics;
- . Mineral Chemistry; voltaic solar cells, batteries for locomotion, low energy aluminium production;
- . Mineral Engineering; anaerobic digestion, flash pyrolysis of coal;
- . Mineralogy; uranium mineralisation;
- . Mineral Physics; coal and uranium utilisation and beneficiation;
- . Plant Industry; rising carbon dioxide levels, energy conservation;
- . Process Technology; coal liquefaction, utilisation and transport;
- . Solar Engineering Unit; solar heating demonstration and development; and
- . Textile Physics; coal conversion and self-ignition.

18.4.3 The Australian Atomic Energy Commission Research Establishment, located at Lucas Heights, is the largest single research establishment in the energy area in Australia. It is operated by the Nuclear Science and Technology Branch of the Australian Atomic Energy Commission and employs 1148 of the 1270 staff of the Commission (March 1978). About 30% of these are professional staff. Of the total 1976-77 expenditure of \$22.4million by the Commission, \$19.4million was expended at the Research Establishment. The research effort of the Establishment is divided between three major program areas and some smaller Divisional programs. The 1976-77 expenditure on that part of each of these programs which is related to energy was estimated for Project SCORE to be as listed in Table 18.1. It shows that approximately one-half of the Research Establishment expenditure is on energy-related R&D.

18.4.4 The energy related programs are carried out within Divisions and program units as follows:

- . Power and Energy Unit; assessment of Australian and international information and data on energy, application and use of nuclear power and implications for uranium demand, modelling studies of energy supply and demand;
- . Uranium Fuel Cycle Unit; assessment of the demand for uranium and uranium enrichment;
- . Divisions:
 - Physics; physics of fission reactors and systems, nuclear fusion, physics of environmental problems;
 - Materials; materials behaviour in fission and fusion reactor systems, mechanical performance of materials for uranium enrichment, photo-electric, chemical conversion of solar energy;
 - Engineering Research; heat transfer and fluid flow in, and safety of, fission reactor systems, residential solar energy;
 - Chemical Technology; corrosion processes, extraction of uranium, upgrading of uranium products, laser method for uranium enrichment, treatment of wastes;
 - Isotope; coal analysis, hydrology, on-stream analysis of minerals;
 - Instrumentation and Control; instrumentation (control and safety) and reliability analysis for fission reactors;
 - Health Physics; ecological and environmental effects of energy conversion, power production, and mineral extraction; and

- Centrifuge Enrichment Project; research into, and the development and demonstration of, centrifugal enrichment.

TABLE 18.1

AAEC EXPENDITURE RELATED TO ENERGY R&D - 1976-77

(figures provided for Project SCORE)

	\$million
(i) Power and Energy	3.62
(ii) Uranium Fuel Cycle	4.82
(iii) Nuclear Science and Applications	0.59
(iv) Divisional Research	<u>0.09</u>
Total	<u>9.12</u>

18.4.5 The Defence Science and Technology Organisation has four major establishments, each of which conducts some programs relating to energy.

The Aeronautical Research Laboratories (ARL) Melbourne, have approximately 200 professional and 300 support staff. The programs include aircraft engine studies, especially combustion problems, and energy conversion. The energy conversion program relates to the maintenance of an assured supply of hydrocarbon fuel for aviation.

The Materials Research Laboratories (MRL) located at Maribyrnong in Victoria, Alexandria in NSW and Innisfail in Queensland have 330 professional and 450 support staff. While problems of materials are of significance in much energy R&D, the MRL programs of specific relevance here are the performance of container materials and avoidance of contamination during storage of liquid fuel, lubricants and hydraulic fluids.

The Engineering Development Establishment (EDE), also located at Maribyrnong has a total staff of 370 of whom about 100 are professionally qualified. Its programs include the design of portable electricity-generating sets and the determination of engine efficiencies for various fuel blends, especially those involving methanol.

The Defence Research Centre, Salisbury has a total staff of 3,441 of whom 476 are professional research workers. The major energy R&D projects are concerned with solid propellant fuels.

UTILITIES LABORATORIES

18.4.6 The Herman Research Laboratory of the State Electricity Commission of Victoria, located at Richmond, Victoria, undertakes approximately one quarter of all the R&D work of the Commission. It has developed a world-recognised, special expertise in all aspects of the chemistry and technology of brown coal extraction, processing and use, and in the application of fluid mechanics in industry. The staff of the Laboratory is approximately 140 of whom 70 are professionally qualified.

18.4.7 The Central Scientific Laboratories of the Gas and Fuel Corporation of Victoria were established at Port Melbourne in 1966 to undertake research, development and testing for the Corporation. The Laboratories also contribute substantially to the work of the Australian Gas Association in developing codes and in testing appliances. The Laboratories employ 31 professional and 38 support staff and are the largest laboratories of the gas utilities.

18.4.8 All major gas utilities in urban areas maintain research, development and testing laboratories. Several are studying methods of using gas boosting for solar water heaters and some are studying the economics of large-scale pipeline networks, but the majority of the effort in the laboratories of gas utilities tends to be expended on appliance and meter testing.

CONSULTANTS

18.4.9 The Australian Coal Industry Research Laboratories Limited (ACIRL) is a private non-profit company formed in 1965 as a result of recommendations made to the Commonwealth Government by the Coal Utilisation Advisory Committee in 1962. It maintains laboratories at Rockhampton and Ipswich in Queensland, Maitland and Bellambi in NSW, and has a central laboratory at North Ryde, NSW. Of the staff of approximately 140, about one-quarter are professionally qualified. The major portion of the funding for ACIRL, which has a total budget of approximately \$3million p.a., is from the coal industry through research and development contracts. This work is reported in confidence to the companies concerned. The Commonwealth Government, in the past, provided some funds for research on the advice of the National Coal Research Advisory Committee (NCRAC). Those funds, amounting to \$300,000 in 1976-77, were required to be matched by the industry including the State coal bodies. An additional \$100,000 p.a. for coal conversion studies was provided by the Commonwealth on a non-matching basis for three years from 1974. NCRAC's functions have now been incorporated in the activities of the National Energy Research Development and Demonstration Council.

18.4.10 The Australian Mineral Development Laboratories (Amdel) is located at Frewville, a suburb of Adelaide. Amdel is a statutory body supported by guarantors. Of a total expenditure of \$2.6million in 1976-77,

approximately 28% was contracted by members of Australian Minerals Industries Research Association Limited, 30% was contracted by the South Australian Government, 10% by the Commonwealth Government, and the remaining 32% was contracted by other clients. The total staff of Amdel is approximately 160 of whom 75 are professionally qualified. At present four of the projects relate to energy and expenditure on these projects is of the order of \$50,000 p.a. Amdel anticipates that contracted work on energy-related projects will expand in the near future.

18.4.11 The Sugar Research Institute was founded in 1949 as a limited guarantee company, Sugar Research Limited, financed by 26 Queensland sugar mills. All 31 Queensland mills are now members of the Institute. Since 1967 the Commonwealth Government has participated in the funding of the Institute on a \$1 for \$2 basis up to a limit which is currently \$400,000. Commonwealth Government funds are channeled through CSIRO who appoint two of the six Directors of the Board of Sugar Research Limited. The laboratories of the Institute are situated at Mackay. All aspects of sugar cane harvesting, transport and processing, other than agricultural aspects, are studied and some research is taken through to the factory scale demonstration stage prior to implementation by member mills. The annual research budget is approximately \$1.8million and although a small part only of this is specifically related to energy, a large part could be deemed to be relevant to any major expansion of the industry to produce the quantities of industrial-grade ethanol necessary for the production of blended fuels for transport.

18.4.12 The Snowy Mountains Engineering Corporation and many other consulting engineering practices in Australia offer advice to clients on energy systems and conservation, some of which may require R&D activity. Several major, international, consulting organisations also have established offices in Australia, but specific research and development work is contracted to the overseas laboratories of their parent companies.

MAJOR INDUSTRIAL LABORATORIES

18.4.13 The Broken Hill Proprietary Company Limited (BHP) maintains two major research laboratories; the Central Research Laboratories (BHP-CRL) at Shortland, NSW, and the Melbourne Research Laboratories (BHP-MRL). A large part of the work of both laboratories is energy-related. The total R&D expenditure exceeds \$5million in these laboratories and, of this, roughly \$2.2million can be designated as energy R&D. The laboratories together employ 300 people of whom 110 are professionally qualified. The major energy-related programs at BHP-CRL relate to coal mining, coking studies and coal conversion while those at BHP-MRL are on coal liquefaction by direct hydrogenation and on solar cooling systems (under contract to AMIRA). BHP-MRL also houses the Haematite Oil and Gas Laboratory of the BHP Oil and Gas Division with a staff of four professionals. This is a well-instrumented facility for assessing the properties of natural and synthetic hydrocarbon products.

BHP also has three works research laboratories at the steel plants at Port Kembla, Newcastle and Whyalla. These laboratories together employ a total of 190 people of whom 63 are professionals. Substantial energy-related programs on coal assessment, coal preparation and coking studies with particular reference to the steel industry are being carried out by these groups.

18.4.14 CSR Limited has interests in the mining and export of coal and supports research in these areas primarily at its facilities at Roseville. At the present time about 20% of the research effort at Roseville is being directed to energy R&D projects embracing coal conversion and ethanol from renewable agricultural resources. Five professional research workers are involved with these projects and the expenditure currently amounts to about \$300,000 p.a. In addition, various operating divisions of CSR have development groups concerned, inter alia, with energy research, including conservation.

18.4.15 British Petroleum Company of Australia Ltd (BP Australia) has recently established a coal research and development laboratory employing four full-time and one part-time professional research workers. The programs of the laboratory are co-ordinated with those of the BP companies in England and France and are concentrated on the special nature of Australian coals. In particular, assessment of coals and methods of upgrading them to higher value products of interest to the oil industry, including conversion to oil and gas, are being studied.

TERTIARY EDUCATION CENTRES

18.4.16 A significant number of academic staff members in a diverse range of disciplines is engaged either directly or indirectly on energy research. To aid the viability of these activities both scientifically and financially, to encourage co-operative programs and to avoid unnecessary duplication of effort and apparatus, some universities have established centres, foundations or institutes. Typical of these are: the Institute for Energy Studies, Flinders University; the Energy Research Centre, University of Sydney; and the Solar Energy Research Committee, University of Queensland.

18.4.17 The University of Sydney Energy Research Centre co-ordinates activity in, and support for, nuclear fusion and plasma research, solar collectors, biochemical and photobiological conversion processes and wind turbine development. The main funding for the Centre until the end of 1977 was from the University Development Grant and the 1977 budget for the Centre, including a component of academic staff salaries, was of the order of \$300,000 of which approximately \$100,000 was from University Development funds. From the beginning of 1978, funding has mainly come from the University Research Grant and funds made available by the NSW Government (\$1.08million over three years). Additionally, the first \$3.5million of a promised grant of \$5million has been received from Prince Nawaf of Saudi Arabia for the high temperature, solar-collector program. Approximately five academic staff, six equivalent-full-time professional

staff and seven postgraduate research students are directly involved in the work of the Centre. Individual projects in the overall program attract support from the Australian Research Grants Committee (ARGC) and other sources.

18.4.18 The Solar Energy Research Committee of the University of Queensland co-ordinates the work of 20 academic staff members spread over five departments in four faculties. The annual budget, excluding established staff salaries, was \$130,000 in 1977 and supported 15 projects.

18.4.19 The Flinders University Institute for Energy Studies co-ordinates work in energy R&D with an annual budget currently of the order of \$120,000 p.a. derived from ARGC, SA State Government and industrial research grants, and from the University. Approximately 12 academic staff, 3 postgraduate students, 2 professional support staff and 3 ancillary staff are involved with the programs of the Institute.

18.4.20 Expenditure (including salaries) on energy R&D by the Research School of Physical Sciences within the Institute for Advanced Studies of the Australian National University is of the order of \$170,000 p.a. on solar energy and \$250,000 p.a. on plasma physics. The work involves 10 full-time professional and 20 full-time ancillary staff.

18.4.21 Besides the work associated with the above centres there is a large number of energy R&D programs in a variety of departments in tertiary education institutions.

18.5 DESCRIPTION OF MAJOR R&D PROGRAMS

ENERGY SOURCES AND THEIR PROCESSING

Coal extraction

18.5.1 While there has been a very significant increase in Australian production of coal from open-cut mines in recent years, there has also been steady growth in underground production, and medium to long term growth prospects for the industry will of necessity involve additional underground production and at greater depths. Major R&D programs in support of this growth will focus on:

- improved seam recovery, particularly at greater depths;
- extending application and efficiency of open cut mining;

- . control and removal of water in mines;
- . development of safe and acceptable methods for utilisation or disposal of mine wastes; and
- . surface subsidence and spoil pile stability.

The Australian Coal Industry Research Laboratories (ACIRL) has accorded the highest priority to mine design and mining methods in a program involving a research team of 17, of whom 12 are professional engineers and scientists. The CSIRO Division of Applied Geomechanics undertakes research into improving methods of extraction of coal from both underground and open-cut mines; approximately 11 professional man-years are devoted annually to this activity.

18.5.2 The ability to predict, monitor and control rock stresses during the mining operation is of importance in underground mining operations, and is being developed by BHP through the Rock Mechanics and Strata Control group in Wollongong. In 1976-77, this work involved seven professional and nine support staff. The CSIRO Divisions of Applied Geomechanics and Mineral Physics are collaborating on a project aimed at determining the significance of geological factors on coal recovery and mine stability. Other topics such as mathematical modelling, and the correlation of surface geological features and rock noise with mine stability are being examined by BHP and others.

18.5.3 ACIRL, BHP and CSIRO are studying mine de-gassing, and the control of outbursts and of spontaneous combustion. The gasification of coal in situ is being studied by the University of Newcastle.

Coal assessment

18.5.4 Classification and assessment of Australian coals according to their suitability for coke-making, power-generation and conversion to liquid fuels is an important area of activity and is being undertaken by BHP at its corporate and plant research laboratories (see 18.4.13), at ACIRL and at the BP Australia Coal Research Laboratory. The recent approach to this problem at the BHP Central Research Laboratories (BHP-CRL) seeks to relate the coal classification and assessment to the chemical constitution of the coal. The research programs at BHP-CRL involve the full-time-equivalent of six professional staff and have an annual budget of the order of \$300,000.

18.5.5 The established system [8] of coal classification and assessment devised by the CSIRO Fuel Geoscience Unit is based on the physical characteristics of the coal and has received wide acceptance both in Australia and overseas. Eight professional research staff are involved in this program which, in 1976-77, cost \$458,000. The Australian Atomic Energy Commission is investigating nuclear techniques for the on-line analysis of coal for energy, ash and moisture content.

18.5.6 The Victorian Brown Coal Research and Development Committee has commissioned a major program for the assessment of brown coal at the

Herman Research Laboratory of the State Electricity Commission of Victoria. The Central Research Laboratory of the Gas and Fuel Corporation of Victoria is also engaged in the classification and assessment of Victorian brown coal.

Coal preparation

18.5.7 Coal washing and flotation methods are being studied at BHP-CRL in a \$320,000 per annum program involving 6 professional and 13 supporting full-time-equivalent staff. Special attention is being given to the development of methods for flocculating particles in suspension, known as ultra-fines, so that they can contribute to greater coal recoveries from washeries and can overcome the environmental problems of settling lagoons.

18.5.8 ACIRL maintains Coal Preparation Research Stations at Maitland, New South Wales, and Rockhampton, Queensland, to treat small or large samples of coal under nearly full-scale commercial conditions. The use of washery-reject coals is the subject of a program sponsored by the State Electricity Commission of Queensland. Conversion of washery slimes, tailings and coarser reject material to inert, useful ash residues by fluidised bed combustion has given encouraging results at laboratory level in a CSIRO Mineral Research Laboratories' project and a two tonne per hour pilot plant is being installed at a commercial coal washery.

18.5.9 Milling of coal is being studied at the Herman Research Laboratory, and at the University of Newcastle, in association with the Electricity Commission of New South Wales. Beneficiation of coal by augmenting the maceral content of one stream at the expense of another is being investigated at CSIRO-MRL.

Coal carbonisation

18.5.10 Although Australia has very large resources of coal there are only limited quantities of prime coking coals essential for the production of high strength coke for use in large blast furnaces. Attempts have been, and are being, made to produce a high quality metallurgical coke from normally unsuitable coals. Coke making studies at BHP-CRL involve 6 professional and 12 supporting full-time-equivalent staff and a budget in 1976-77 of \$300,000.

18.5.11 At ACIRL, programs have been designed to incorporate either briquetted, high-volatile, soft coking coal or up to 10% of solvent refined coal (SRC) into coke-oven charges to extend the range of coals for producing metallurgical grade coke. The SRC for this latter work will be derived from the ACIRL hydrogenation facility (see 18.5.19). Briquetting of coal fines to increase their bulk density prior to charging into coke ovens is also being investigated by Conzinc Riotinto of Australia Ltd. The Gas and Fuel Corporation of Victoria is studying the production of activated carbon from brown coal briquettes in a one tonne per week pilot plant.

Coal combustion and gas cleaning

18.5.12 Much Australian electricity-generating plant uses pulverised coal as fuel. No full-scale test facilities for pulverised fuel burners are currently operational in the world and hence the generating industry is dependent on small-scale tests by manufacturers. A feasibility study has recently been completed by ACIRL or a coal combustion-environmental test facility; the study recommends that a facility be established in Australia. The cleaning of exhaust gas from coal-fired boilers and furnaces has been studied for many years with considerable success by the CSIRO Division of Process Technology. Major advances have been made in electrostatic dust precipitation especially in relation to the collection of high resistivity fly ash [9] which is of special significance to Australian black coals. Six professional staff are engaged on this program which has attracted substantial international attention. ACIRL has developed a laboratory technique to make forecasts of the electrostatic precipitability characteristics of fly ash from coal bore cores, partly based on earlier work at the University of Wollongong. The problems of precipitating fly ash from brown coals are being studied by the State Electricity Commission of Victoria.

18.5.13 Related studies include investigations and computer-modelling of furnaces, and of ignition and ash formation in pulverised fuel flames at the University of Newcastle; investigations of mixtures of brown coal and oil for use as a possible fuel at the University of Melbourne; the study of mechanisms of electrostatic precipitation at the University of Wollongong; and the study of aerodynamic design methods for the flow through precipitators and of instabilities in fluidised-bed, combustion systems at the University of Adelaide.

Coal conversion

18.5.14 Conversion of coal to other forms of fuel is a means by which the range of uses of coal can be greatly extended. The major program on gasification in Australia at the present time is the development of the 'OXAR' (oxidation and reduction) process at BHP-CRL, which originally arose to meet the need for an efficient source of gas in the AUSCOKE process [10]. The product can be tailored to be either a combustion gas or a synthesis gas; in the latter case it could be suitable as a feedstock for synthesis of liquid fuels. A US patent for the process has been granted and others are being negotiated. Coal gasification research, performed in the CSIRO Division of Process Technology in the early 1960's, is being revived and the suitability of a range of Australian coals for gasification is being assessed; it involves 16 professional and 12 support staff.

18.5.15 A bench-scale, continuous, catalytic-hydrogenation reactor is being used at the BHP-Melbourne Research Laboratories to examine the potential of Australian coals for liquefaction. The work was begun to satisfy a condition of the granting to BHP of an exploration lease in the Galilee Basin of Central Queensland, but is now being continued as a project of the BHP Oil and Gas Division. A project is also being carried out at the BHP-Central Research Laboratories on the evaluation of solvent-

refined coal as an additive to coking coals, as a starting point for hydrogenation to liquid fuels, and as a replacement for heavy fuel oil. The total BHP coal conversion program involves seven professionals and four support staff with an expenditure of \$350,000 in 1976-77.

18.5.16 Hydrogenation of coal is also the conversion process selected for study by CSR Ltd with the aims of assessing some Australian coals for the process and of building experience in the area. The program began in June 1975, has a current budget of approximately \$200,000 per annum and includes three equivalent-full-time professional staff and one assistant.

18.5.17 Several divisions of CSIRO are studying direct catalytic hydrogenation of coal and particularly the deactivation of the catalyst by trace metals or by coke deposition.

18.5.18 The simplest of the methods of obtaining liquids from coal is pyrolysis. The CSIRO Fuel Geoscience Unit and Divisions of Process Technology, Mineral Engineering, and Applied Organic Chemistry are collaborating on the development of fluidised bed 'flash pyrolysis', including assessment of ways in which the products may be used or further treated. Both a continuous micro-reactor and a half-tonne per day plant are being used. Early yields from the larger plant agree well with the scaled micro-reactor yield. The liquid and gas produced can be processed to yield lighter hydrocarbon liquids more suited to transport needs. The char can also be treated further, but its potential for direct use as a power station fuel is being assessed both in the CSIRO program and at the University of Newcastle. At the latter a system of pyrolysis plant with integral hydrogen production for hydrogenation of tars, combined with a conventional power station, has been devised.

18.5.19 Solvent refining of coal, in which a process-derived solvent donates hydrogen to the coal, is being studied both in autoclave batches and in a one tonne per day continuous reactor at the Australian Coal Industry Research Laboratories (ACIRL). The process is basically the SRC (solvent refined coal) process. ACIRL favour the process for the first stage of a commercial coal conversion program from which income could be generated, through sale of products to provide cash-flow for further hydrogenation or synthesis stages.

18.5.20 The choice of conversion process depends intimately on the fundamental chemical and physical properties of the coal feedstock. Much of the program commissioned by the Victorian Brown Coal R&D Committee at the Herman Research Laboratory, an ARGC-supported program in the Department of Chemical Engineering at the University of Melbourne, and a CSIRO program, are concerned with studies of the chemistry of brown coals and the development of methods of pre-treating these coals prior to liquefaction. The Victorian Brown Coal R&D Committee also supports brown coal research projects at the Royal Melbourne Institute of Technology, the University of Melbourne, Monash University and the Gippsland Institute of Advanced Education.

18.5.21 The State Electricity Commission of Queensland has recently committed \$125,000 per annum for two years to a project to determine the suitability of Walloon coals for gasification and liquefaction. Similar types of study are being undertaken by the BP Coal Research Laboratories.

Crude petroleum and petroleum products

18.5.22 Petroleum-reservoir engineering, including extraction technology is being studied in the Department of Chemical Engineering of the University of Sydney and a postgraduate degree and a diploma program in the subject are offered from 1978.

18.5.23 The study of oil and gas occurrences, including the conditions of formation and migration of hydrocarbons, the relations between source rock and hydro-carbon occurrence and availability, and the biodegradation of hydrocarbons, is being undertaken in the Fuel Geoscience Unit of CSIRO-MRL. This project involves three professional research staff. The same unit is also developing portable, super-sensitive, gas chromatographic equipment to locate hydrocarbons by 'sniffing' water, earth or air above suspected fields. A land-based version of the equipment is expected to become available commercially within three years and, providing resources are available, the sea-based version will be developed in parallel within the same time scale.

18.5.24 Valuable by-products from the production of natural gas are the liquefiable components of which liquid petroleum gas (LPG) is the most important. Its use as a fuel in motor vehicles is well established but its more general performance characteristics are being assessed in a joint program by the Engineering Development Establishment (EDE) and the Aeronautical Research Laboratories (ARL) within the Defence Science and Technology Organisation. Some research into applications of LPG is involved in the joint Shell group/BHP venture to develop its use as an automotive fuel. A similar study by EDE relates to the use in engines of various blends with methanol. Various routes exist for the production of methanol including that from natural gas, but the efficiency of this conversion process is poor.

18.5.25 Most R&D associated with the refining of crude oil is done in the overseas laboratories of the refining companies, but some subsequent development of this technology occurs at local refineries. Typical of this type of development is the use of zeolite catalysts and 'riser' cracking in the catalytic cracking process and of bi-metallic catalysts in the reforming and desulphurisation processes by Shell Refining, Australia, Pty Ltd. R&D related to the environmental impact of refining operations is conducted by refining companies in Australia.

Hydro-energy

18.5.26 The remaining potential for new hydro-electric power generation sites in Australia is small. R&D associated with these sites relates primarily to environmental matters as the technology is already well

established. The major study of this type (\$300,000 p.a.) has been largely contracted to relevant departments of the University of Tasmania by the Hydro-Electric Commission of Tasmania and concerns the past, present and probable future ecology of the area, in relation to the proposed lower Gordon River scheme.

18.5.27 Tidal energy systems have been devised and assessed by the WA Energy Commission for several sites in the north-west of Western Australia. While no research of this nature is current, a watching brief is being maintained by the Commission.

Uranium exploration, extraction and upgrading

18.5.28 Following a Ministerial statement in February 1976, the uranium exploration program of the Australian Atomic Energy Commission (AAEC) was phased out in favour of exploration by private companies. However, the Commission has retained a small group of geologists and mining engineers to provide independent evaluation of Australia's uranium resources based on data provided by companies; to provide advice to the Government on matters relating to uranium exploration and development; to contribute to Australia's international obligations in supplying data; to participate in international aid projects; and to enable the Commission to fulfil its responsibilities as the agent of the Government in the Ranger Project. At the Research Establishment (see 18.4.3), the Commission has facilities for the rapid analysis of uranium samples and industry makes considerable use of these facilities.

18.5.29 In the CSIRO Divisions of Mineralogy and Mineral Physics the origin and geochemistry of uraniferous deposits are being examined to establish the stratigraphic association of uranium occurrences. Methods of tracing the origin of traces of uranium found in salt lakes are also being developed as an aid to uranium exploration. A total of six professional staff is employed on these programs.

18.5.30 Improved techniques for the continuous sorting of the inhomogeneous uranium ores into graded stockpiles are being developed by the CSIRO-MRL in a program involving two professional staff. Other research on upgrading is current at Amdel and at the AAEC where both improved physical and chemical methods of extracting uranium from the ore are being developed. An experimental plant for the manufacture of uranium hexafluoride from yellow-cake using a process patented by the AAEC is also being operated. Pure uranium oxide powder and fuel pellets for nuclear power plant are also produced on an experimental scale.

18.5.31 Both conventional and novel methods of treating waste water streams from uranium mining and milling operations are being investigated by the AAEC. Other management systems for radioactive waste are also being studied as part of Australia's contribution, through the Commission, to the work of the International Atomic Energy Agency and the OECD Nuclear Energy Agency.

Uranium enrichment

18.5.32 Approximately 85% of the research effort of the AAEC on the uranium fuel cycle, which represents 17% of all the work of the Research Divisions of the Nuclear Science and Technology Branch (see 18.4.3), is R&D on uranium enrichment. This work also absorbs about one-quarter of the effort of the Engineering Services Branch.

18.5.33 Two methods for isotopic enrichment are being studied to provide a technical basis for the option to construct and operate a commercial plant in Australia. Enrichment of uranium hexafluoride in a gas centrifuge has been studied since 1965 and continues to absorb the major part of the enrichment research effort. Materials and mechanical engineering problems associated with slender cylinders rotating at speeds approaching 50,000 rpm and producing forces exceeding by 200,000-fold that of gravity have dominated the program. A small prototype plant with full-scale centrifuge modules is operating. The Commission is supporting related work in industry.

18.5.34 Uranium enrichment by laser-photochemical methods devised by the AAEC has been demonstrated experimentally on a milligram scale using a pulsed carbon dioxide laser designed at Lucas Heights. Further development of both the process and the laser is continuing. Laser separation of isotopes is also supported by the Australian Institute for Nuclear Science and Engineering (AINSE) at the University of Sydney.

Fission reactors

18.5.35 At 30 June 1977, about 80% of the power and energy research within the AAEC was devoted to studies relating to the performance and safety of nuclear fission reactors. Research programs cover neutron and reactor physics, behaviour of fuel and other materials under neutron irradiation, thermal-hydraulic analysis, chemistry of reactor coolants, behaviour of systems under loss-of-coolant conditions, analysis of emergency core-cooling and environmental control.

18.5.36 AINSE is supporting related studies at a number of universities. In addition, a substantial number of fundamental research projects in nuclear physics, chemistry and engineering have AINSE financial backing for use of AAEC facilities. Some are supported by ARGC and some through AAEC research contracts.

18.5.37 Because of the considerable importance attached to the use of a research reactor and because of the need to ensure that radio-isotope production can continue into the future, a feasibility and design study for a new research reactor, of medium power, for the production of radio-isotopes has been mounted by the AAEC. Some studies of overseas designs will be necessary and these may result in tests being carried out by research divisions to provide performance and safety data. The study has been approved in principle at an estimated cost of \$4million, spread over four years, as a separate item from the main AAEC budget. However, approval for expenditure is required each year.

Nuclear fusion

18.5.38 After supporting plasma physics in universities through AINSE for many years, the AAEC has commenced a direct involvement in fusion R&D. Agreements with some universities have been concluded for the attachment of research staff to schools undertaking research in plasma physics (Flinders, Sydney, ANU).

18.5.39 Co-ordination of its extended activities with university staff is being discussed so that a national fusion research program can be developed. Consideration is being given to designs for equipment which will allow AAEC and universities (through AINSE) to make contributions to international research on nuclear fusion. The problems associated with materials to be used in fusion reactors will be studied since constructional materials such as metals and ceramics will be subject to extremely severe environments. Other studies on engineering, safety and environmental aspects will be carried out.

18.5.40 The Australian Research Grants Committee (ARGC) supports research on plasma physics at the University of Sydney and at Flinders University. Increasing support is also being given in this area by AINSE to other groups in several universities including the Australian National University (ANU). In 1978 the Research School of Physical Sciences at the ANU has made \$250,000 available for plasma physics research which is mainly devoted to studies involving Tokamak devices.

18.5.41 Australia is one of the 10 nations represented on the International Fusion Research Council.

Direct solar heating

18.5.42 Existing technology can provide solar-heated water at temperatures up to 85°C, and the prime need in this temperature range is improving the design and manufacturing methods to reduce the production costs of solar absorption systems to enable the transfer of the technology into industry and commerce. Adoption of solar heating in industrial and commercial applications will also require demonstration of existing and developing technologies. The CSIRO Solar Engineering Unit (SEU), comprising four professional staff members, is providing technical and financial support for demonstration projects. One such project is operating successfully in a soft-drink factory in Queanbeyan NSW, and a second in which Amdel and the SA Government will participate, is about to begin in an Adelaide brewery. In WA, solar energy is being used to provide hot water in a factory producing photographic products. The Energy Authority of NSW is sponsoring an integrated solar and waste heat recovery system for a pet-food factory in NSW.

18.5.43 Work is proceeding in government, industry and tertiary education institutions on solar collector testing. A range of large-scale test facilities has been developed by CSIRO, including timber drying plants, water desalination units, and units for industrial heating. Comparisons are being made of actual performance with computer-based predictions and

involve an international exchange of personnel. The results are of value in determining test procedures for collectors. Performance tests for domestic, solar, hot-water systems are being developed by the State Electricity Commission of Victoria with the concurrence of solar appliance manufacturers. Currently the Standards Association of Australia is developing standards for solar domestic water systems.

18.5.44 The CSIRO Division of Mechanical Engineering, solar appliance manufacturers, some gas utilities, and several universities, are active in the development of collector-booster systems for water heating. A feature of gas appliance development, including the solar boosting systems, is the replacement of wasteful pilot lights by fail-safe, electronic, ignition systems.

18.5.45 Several centres are studying methods of achieving higher temperatures. These methods include: evacuated tube collectors, which are being studied by CSIRO, and at the University of Sydney; the development of selective surfaces for solar collectors at the University of Sydney, at CSIRO and the NSW Institute of Technology; and the use of various methods to concentrate the solar radiation, primarily at the ANU and the University of NSW.

18.5.46 Solar air heaters have application in industrial drying and in domestic and commercial space heating and cooling systems. Devices are being studied at the CSIRO Division of Mechanical Engineering, the James Cook University of North Queensland, the University of NSW and the University of Adelaide. Solar-boosted, heat-pump systems are being developed at the University of Melbourne with support from the Electrical Research Board.

Solar powered cooling systems

18.5.47 The potential for solar energy utilisation in remote mining areas is being explored by BHP-Melbourne Research Laboratories (BHP-MRL) with support from Groote Eylandt Mining Co Pty Ltd (a BHP subsidiary) and from the Australian Mineral Industries Research Association (AMIRA) through a contract supported by a group of 13 companies in the mining and manufacturing industries. The project is stimulated by the high cost of electricity, and of maintenance, in such areas and by the need for comfort cooling such that 30% of the energy generated is used for air-conditioning. The program involves the study of collector development, the performance of semi-commercial solar cooling systems and the development of a solar-mechanical convertor based on a Rankine-cycle engine. A solar-powered, absorption, refrigeration system is being set up at Groote Eylandt for BHP while two solar cooled houses are being built at Port Hedland and Paraburdoo for AMIRA. A co-operative program is being set up with the Solar Energy Research Institute of Western Australia for monitoring of performance of these houses, which will utilise integrated roofing systems developed by the AMIRA group. The BHP-MRL program involves two professionals and two support staff. Solar-powered, absorption, refrigeration systems are also being studied in the Departments of Mechanical Engineering at the Universities of Queensland, Melbourne and

Sydney (the Queensland Department has many years of experience in this area) and in the Department of Chemical Engineering, University of Adelaide, with support from the State Energy Research Advisory Committee of South Australia. A large-scale solar heating and cooling plant has recently been commissioned at the Eldridge Medical Clinic in Bankstown, NSW.

18.5.48 Alternative methods of using solar energy for cooling are being developed by CSIRO, in association with several manufacturers. These methods seek to use evaporative cooling without the complication of increased humidity. The use of the endothermic heat of solution of some salts as a means of obtaining cooling from low temperature solar energy is the subject of patent applications by Applied Research of Australia which has also developed educational solar collectors now being sold in several countries.

Design of thermal systems

18.5.49 Computer-modelling of solar-energy systems of given configuration is part of the programs at CSIRO, the Universities of Melbourne, Queensland and NSW, and the James Cook University of North Queensland. A method of synthesising the optimum combination of collector area, thermal storage and auxiliary heating in a system has been developed at the University of Adelaide.

Solar energy storage

18.5.50 Types and configurations of thermal storage systems for use in solar energy systems have been studied by the CSIRO for many years. Chemical storage is incorporated in the high temperature solar energy system being developed at the Australian National University (see 18.5.51). At Flinders University several routes by which solar energy can be stored chemically as hydrogen are being explored and studies of the chemical and materials problems associated with the large scale reticulation and use of hydrogen, the 'hydrogen economy', are in progress. One route which is attracting attention combines the collection and storage of solar energy using photochemical cells in which water can be dissociated to hydrogen and oxygen by photo-excitation in the presence of catalysts. Electricity has also been generated in such cells. These and related photochemical phenomena are also being studied at the University of Adelaide; at the University of Queensland where two academic staff members and six other professional staff are involved; and at the University of NSW. At the CSIRO Division of Applied Organic Chemistry four professional staff are working in this area and programs also exist in the CSIRO Division of Mineral Chemistry and at the University of Western Australia.

Solar-electrical conversion

18.5.51 At the Research School of Physical Sciences, Australian National University, concentrated solar heat is used to dissociate ammonia to hydrogen and nitrogen at high pressure. The incorporation of heat

exchangers in the reactors allows the dissociation products to be piped in uninsulated pipes at atmospheric temperature either to storage or directly to recombination reactors which can act as the heat source for conventional thermal electric power plant. The system differs from the 'power tower' concept being developed in the USA especially in its storage capability.

18.5.52 A solar-powered Rankine engine, similar to the French 'ORMAT Energy Converter', is envisaged by the Department of Electrical Engineering of the University of Queensland as being suitable for power generation in remote communities. This project is supported by the Electrical Research Board and the State Electricity Commission of Queensland.

18.5.53 A range of small electric-power generators employing photovoltaic cells to charge batteries used in communications systems has been developed by the Headquarters Building Branch of Telecom Australia over several years; a substantial system has been commissioned recently to power the Tennant Creek - Alice Springs microwave, trunk-communications link. Other research on applications is being done by Amalgamated Wireless (Australasia) Limited, and by Lucas Industries Australia. Basic studies of semiconductor, photovoltaic cells are in progress at several universities. In particular, at the University of NSW, a new method of fabricating silicon solar cells which eliminates a major cost component and produces cells of enhanced performance is being developed. Work at the University of Queensland on thin-film photovoltaic cells using electrodeposition techniques has been reported recently. It promises advances in this method of producing solar cells, which would also reduce costs significantly. The AAEC is studying the conversion of solar energy to electrical energy and hydrogen generation using photo-electrochemical cells with electrodes consisting of semi-conducting oxide layers on metals.

18.5.54 At the University of New England, means of generating electricity from solar energy utilising the thermo-electric effect are being studied.

18.5.55 Various projects on the small-scale use of wind energy for electrical power generation exist in government laboratories, universities, colleges and industrial companies. The Defence Research Centre, Salisbury is developing a portable Darrieus wind turbine to power communications equipment, and Dunlite, a division of Pye Industries Sales Pty Ltd, which has an international market for 1kW wind generators, is developing a 5kW, horizontal-axis unit and associated generating and control equipment.

Measurement of solar radiation

18.5.56 Solar radiation data have been collected by a number of groups, including the Division of Atmospheric Physics of CSIRO, the Bureau of Meteorology and the Waite Agricultural Research Institute of the University of Adelaide. Several projects to establish continuous data recording stations in high population areas are in progress, notably those at the University of NSW, Flinders University and the South Australian Institute of Technology. Instrumentation for the automatic collection of solar energy

data has been developed in the Research School of Physical Sciences, ANU. Arrangements are being made to install these instruments in field situations in Victoria and WA.

18.5.57 In the CSIRO Division of Mechanical Engineering, and at the Capricornia College of Advanced Education, methods are being developed of presenting solar radiation data on horizontal and inclined surfaces for use in the design of solar collector systems.

Solar production of fuels

18.5.58 Methane production via anaerobic digestion, usually from food or animal wastes, or producer gas production from garbage or cellulosic wastes, is primarily a waste disposal process which requires no external energy input. Such systems are being studied extensively by the CSIRO Divisions of Chemical Technology, Food Research, and Mineral Engineering, by the CSIRO Agro-industrial Unit, by the University of Sydney where a pilot-scale, continuous digester is in operation, and in various colleges of advanced education.

18.5.59 The CSIRO Division of Chemical Technology is devoting a large proportion of its research effort (16 professional staff) to a study of a process involving the integration of anaerobic digestion of cellulose with photo-synthetic conversion of the carbon dioxide contaminant of the methane from the digester, using an algal pond from which liquid hydrocarbons can be extracted and the residue recycled through the digester. Protein production and products derived from cellulose fibre can be integrated with this process, and waste carbon dioxide from power stations might also be used.

18.5.60 Potable and industrial grade ethyl alcohol (ethanol) is produced commercially by a batch process from molasses, and a substantial export market has been established by CSR Limited. Ethanol can also be produced from cellulose, sugars or starches and is an attractive fuel for use in internal combustion engines.

18.5.61 A laboratory-scale, continuous, sugar fermenter is in operation in the Department of Chemical Engineering of the University of Sydney as part of the program of the Energy Research Centre.

18.5.62 The CSIRO Divisions of Plant Industry, Land Use Research, and Chemical Technology, and the CSR Limited Distilleries Group, have programs in which the overall energy and economic budgets of large scale production of liquid fuels from crops are being assessed. The CSIRO is studying crops which have a high cellulose yield. Present indications are that areas of land needed to grow fuel crops in sufficient quantities may be unacceptably large though yields per hectare of some crops, such as starch-yielding cassava, could possibly be increased substantially through intensive agronomic studies. The University of Queensland is collaborating with the Queensland Department of Primary Industries and some commercial companies in quantifying growth rates of the cassava crop and in developing high-yield strains.

18.5.63 The use of algae as a source of hydrocarbon fuels is regarded by the Aeronautical Research Laboratories as being potentially of considerable strategic importance. An active program is in progress to examine the growth, harvesting and processing of the alga *botryococcus braunii*.

ENERGY CONVERSION, DISTRIBUTION AND USE

Electricity generation, transmission and use

18.5.64 As electric power systems increase in size and become more interdependent, the need to understand in detail the dynamics of both system components and the overall system, and to devise system controls which are capable of detecting and responding rapidly to component or system faults, and load changes, assumes major importance. All electricity generating authorities conduct or support R&D programs in these areas, especially those in NSW and Victoria. Australia has made important contributions to the international program of the Conference Internationale des Grand Reseaux Electriques particularly on methods of improving the dynamic performance of systems by means of excitation controllers and boiler-turbine controls and their co-ordination with machine governors.

18.5.65 The stability of multi-machine, power systems is being investigated on the actual NSW system by the University of Sydney in association with the Electricity Commission of NSW (ECNSW) and with both basic and special grant support from the Electrical Research Board (ERB). Techniques of estimating the state of a system, the analysis of contingencies, instrumentation, protection, switching control and the electrical consequences of boiler/turbine dynamics are being developed using a laboratory model system at the University of NSW. These programs also receive basic and special grant support from ERB. Other related programs are in progress at the State Electricity Commission of Victoria (SECV). Analysis of demand profiles as influenced by new technology, such as electric vehicles or large scale use of solar heating and cooling systems with electrical boosters, is being undertaken by most generating authorities and some universities.

18.5.66 Disturbances in power systems can arise from many sources including circuit interruption, switching transients, lightning strikes and insulation breakdown. The ERB has awarded substantial grants to the University of Sydney for circuit-interruption studies, and other related work is being undertaken at the University of New England and at the ANU. The integrity of above-ground and underground cable insulation under the influence of switching transients, atmospheric pollution, overheating and moisture intrusion are being studied at Monash University, the Universities of NSW and Queensland and by the SECV and ECNSW. Lightning is a major source of disturbance and, through ERB support over many years, the University of Queensland has become internationally recognised as a centre for research on, and prediction of, the effects of

lightning strikes. Novel methods of signalling potential or real faults in a large system are being developed by SECV, the University of NSW, the James Cook University of North Queensland and several Institutes of Technology.

18.5.67 Other R&D areas related to the solution of immediate electricity generation and transmission problems include: the performance of cooling ponds and associated equipment, by the Water Research Laboratory of the University of NSW; the design of ducts and flumes for conveying liquids and ash slurries, and of ducts for conveying gas, by the SECV Herman Research Laboratory; protection of copper-chrome-arsenic-treated, hardwood, distribution poles from soft rot by the Queensland Department of Forestry and CSIRO; electrostatic dust precipitation by the University of Wollongong and CSIRO; electricity supplies for remote consumers by the University of Queensland; and system planning and maintenance scheduling in relation to reliability criteria by Monash University.

18.5.68 At the University of Sydney, magneto-hydrodynamic power generation which, when combined with conventional fossil fuel generating plant can substantially increase the conversion efficiency, is being studied with ARGC support. Substantial progress has been made towards the evolution of suitable plasma seeds and electrode designs. The facilities developed for this work are also used in the research on circuit-interruption and switching-overvoltage discussed in 18.5.66. The AAEC is studying the potential of an idea for a magneto-hydrodynamic turbine system.

18.5.69 Storage batteries, especially those suitable for electric vehicles, are being developed by manufacturers including Dunlop Australia Ltd where it is understood that a significant improvement in storage-to-weight ratio has been achieved, at Flinders University, and at CSIRO. Advanced work on electric vehicles is in progress at Flinders University and the Tasmanian College of Advanced Education.

Conservation of energy

18.5.70 The National Energy Advisory Committee [11] has made recommendations on an Australian conservation of energy program, the majority of which relate to the transfer of existing information and known technology to industry and to the public. Research activity relating to the program is mainly the gathering and interpretation of data on the end-use of energy. A project of this type has been carried out by the CSIRO Solar Engineering Unit in a section of the food processing industry; more extensive studies covering other industries, with special emphasis on transport, are in progress in other CSIRO Divisions. The Bureau of Transport Economics is also studying patterns of usage of transport vehicles and the Shell Company of Australia has developed improved methods of optimising schedules for delivery vehicles.

18.5.71 The Task-Force on Energy of the Institution of Engineers, Australia [12],[13], with the co-operation of the Institute of Fuel, (now

the Australian Institute of Energy), has reviewed areas of energy wastage in industry and has recommended methods by which establishment of the technology of energy-recovery systems could be accelerated. New energy systems can be designed optimally to incorporate waste-energy recovery using synthesis procedures developed at the University of Adelaide.

18.5.72 Patterns of domestic and commercial consumption of energy are assessed as a normal part of market investigation by suppliers of heating and cooling equipment, of energy for this equipment, and of insulation. Basic data on the performance of plant and insulation, and of buildings in general, are being generated by the CSIRO Division of Building Research, by the Australian Institute of Refrigeration, Air-conditioning and Heating, and by departments in most universities.

18.5.73 A substantial amount of energy is used in the agricultural sector and data on how it is being used are being gathered by CSIRO. Means of reducing rural requirements are also being developed.

Pipelines

18.5.74 Apart from the research on the design of ducts mentioned in 18.5.67, there is some economic and technological assessment of natural-gas, pipeline systems by gas utilities and gas producers, which includes studies of materials for high pressure reticulation systems by the Gas and Fuel Corporation of Victoria. A major pipeline research and development activity in Australia is that at BHP-Central Research Laboratories relating to coal slurries. Methods of selective agglomeration being developed by five professional staff at BHP-CRL could lead to effective, pipeline-transport systems for a wide range of coals and this could simplify greatly many of the present methods of coal handling and preparation. The sociological, environmental and economic consequences of such a dramatic change in the coal industry are also being considered.

NOTES AND REFERENCES

1. Project SCORE (Survey and Comparisons of Research Expenditures), Research and Development in Australia, 1973-74, 2 Vols. Vol. 1, 153pp. Vol. 2, 145pp. Australian Government Publishing Service, Canberra, 1977.
2. National Energy Advisory Committee, 'Proposals for a Research and Development Program for Energy', p.4. Department of National Resources, Canberra, December 1977, 40pp.
3. Report of the Independent Inquiry into the CSIRO, Canberra, 1977, 285pp.
4. The Rt.Hon. P.J. Lynch, 'Budget Speech 1977-78', 1977-78 Budget Paper No. 1, Australian Government Publishing Service, Canberra, 16 August 1977.
5. 'Uranium-Australia's Decision', a collection of Ministerial Statements of 25 August 1977, leaflets, Hansard extracts, background papers and illustrations assembled by the Australian Government Publishing Service, Canberra, 1977.
6. The Rt.Hon. J.D. Anthony, 'Ministerial Statement on Energy Policy', Hansard 7 November 1977, House of Representatives, pp. 2954-2959.
7. CSIRO Annual Report 1976-77, p.32.
8. G.H. Taylor and M. Shibaoka, 'The Rational Use of Australia's Coal Resources', Institute of Fuel (Australia) Biennial Conference, November 1976.
9. C.A.J. Paulson, R.B. Kehane, E.C. Potter, 'Electrostatic Precipitation of Fly-Ash from a Range of Australian Coals', Institute of Fuel (Australia) Biennial Conference, November 1976.
10. T.G. Callcott, 'Coal to Burn?', 44th Melchett Lecture, Journal of the Institute of Fuel, London, June 1977.
11. National Energy Advisory Committee, 'Proposals for an Australian Conservation of Energy Program', Department of National Resources, Canberra, September 1977, 34pp.
12. Task Force on Energy, 'Towards an Energy Policy for Australia', Conference on Energy 1977, The Institution of Engineers, Australia, National Conference Publication No. 77/6, July 1977, 242pp.
13. Task Force on Energy 1977, 'Recommendations for an Energy Policy for Australia', Summary Report and Recommendations, The Institution of Engineers, Australia, October 1977, 28pp.

CHAPTER 19

AGRICULTURE



Photograph: A barley variety called Clipper, which was bred and selected at the Waite Agricultural Research Institute, University of Adelaide. Since its commercial release in 1968, Clipper has become the most widely grown barley variety in Australia, and is estimated to have added approximately \$40million to the value of Australian barley crops because of its increased yield and quality. It is also grown widely in India, Greece and South Africa.

(Photograph courtesy Waite Agricultural Research Institute).

CHAPTER 19

AGRICULTURE

19.1 INTRODUCTION

AGRICULTURE IN AUSTRALIA

19.1.1 The primary process in agricultural production is the fixation of the sun's energy in photosynthesis by green plants and other organisms. The maximum energy conversion of incident radiation by a plant is a mere 5% and it is usually much closer to 1%. Half the sun's energy is not used by plants because their pigments absorb in only two main regions (400-500 nm and 600-700 nm). Losses which occur include reflection, lack of complete quantum efficiency and apparently wasteful respiration. Each year the Earth's surface receives 3×10^{24} Joules of solar radiation of which 3×10^{21} J, that is to say 0.1%, is converted to plant products representing stored energy. Of the energy stored by plants each year only about 0.5% is used domestically while the rest cycles more or less rapidly through the world's biomass. The use of animals in an agricultural system further reduces efficiency of food production in that herbivores convert to body tissue about 10% of the energy stored in their food and man uses a similar percentage of the energy stored in animal tissue. This means that when man eats meat, he is utilising 0.001% of the solar radiation involved in its production. However animals are necessary to ensure a balanced management of land surfaces, particularly for the fragile Australian landscapes, and for the controlled utilisation of range lands.

19.1.2 The resources used for agriculture include fuel, fertilizers, farm machinery, and agricultural chemicals; these all involve manufacture and transport. The primary producer derives these inputs in the main from the Australian economy but sells a large proportion of his product on the international market.

19.1.3 The areas devoted to particular crops are shown in Appendix 19.1 as well as the gross value of the product for the year 1974-75 (Commonwealth Year Book, 1975-76); statistics for animal production are provided in Appendix 19.2. The main features of production are the dominance of cereal crops (about \$1,500million), with horticulture (including vegetables) contributing about \$600million and sugar cane about \$500million. The total value for all crop production was \$3,000million which compares with the total production from animals in the same year of \$2,700million; of the latter, cattle and sheep each contributed about \$1,100million and thus made up more than 80% of the total. The gross value of agricultural production is estimated to have been \$5,400million in 1974-75 and \$6,300million in 1976-77. This amount should not be viewed in

isolation however, since due account needs to be taken of forward and backward linkages to industries beyond the farm gate including manufacturing, transport and other tertiary activities.

19.1.4 In Chapter 9 of Volume 1B of this report, further details are given of the significant features of the agricultural industries in Australia, and of recent trends within the rural sector. Of particular importance, because it is related to the need for R&D, is the decline in the profitability of agricultural enterprises and in real farm income. This decline is evidenced by, among other indicators, the ratio of the index of prices paid (by primary producers for agricultural inputs) to the index of prices received (for agricultural products): taking the ratio in the period 1960-61 to 1962-63 as a standard of 100, the ratio has fallen in recent years from 101 in 1973-74 to 62 in 1975-76 and 57 in 1977-78, (see 'Trends in Australian Agricultural Commodities', Nos. 79, 85, Bureau of Agricultural Economics, Canberra, 1978).

19.1.5 The Australian primary producer is receiving less financial support than is commonly believed by the community. Other groups, such as wage-earners and non-exporting industries, have more opportunity to recoup the costs resulting from tariff protection through increased wages or prices than do the Australian agricultural export industries, which must therefore increase efficiency in order to maintain competitiveness and profitability. Agricultural R&D, which in the main has as its primary purpose the maintenance and improvement of efficiency of production, must play a vital role in achieving this.

19.1.6 The trends discussed in Chapter 9 (sections 9.1, 9.2) have implications not only of an economic nature but also with respect to research and research planning, particularly for strategic research. The establishment of a body with an overview of the whole of agricultural research is also discussed in Chapter 9. As well as farm aggregation as a possible means of increasing efficiency, there is a need for further technical innovation to increase the efficiency of production by such methods as improved varieties, increased fertiliser efficiency and better control of diseases and pests

DEFINITION OF AREA COVERED

19.1.7 Agriculture, for the purposes of this paper, does not include forestry or fisheries or food processing, so that the farm gate sets the boundaries. No attempt has been made to identify separately R&D concerned with harvesting or with agricultural engineering, although work is carried out in these areas. The following definitions follow those of the OECD publication, 'The Management of Agricultural Research', Paris, 1970:

Basic Research - research which has no specific application in view but which is necessary to ensure the advancement of knowledge.

Strategic Research - research which provides a broad basis of knowledge necessary for the solution of specific problems.

Tactical Research - research directed to the solution of specific problems.

Development - commercial adaptation and testing of research results.

19.1.8 It is important to emphasise at the outset that agricultural research - especially strategic, tactical and developmental research - into crop and livestock problems in Australia is, in the main, site specific. In this respect agricultural research differs markedly from medical research, engineering research and mineral processing research. Largely as a result of this there is relatively little over-all organisation of agricultural R&D in Australia. This situation also prevails because of the lack of an overview organisation and the almost complete absence of formal agreements between the organisations involved.

19.1.9 In this chapter agricultural and veterinary research programs are to be discussed under five sections:

- . animal production including animal health and pastures.
- . agricultural plant production;
- . horticultural production;
- . protection of primary production;
- . soils, water and land use research.

19.1.10 In order to make inter-organisational comparisons, comparable groups are considered to be Research Scientists and Experimental Officers in CSIRO, Research Scientists in State departments of agriculture, and academic staff in universities. Postgraduate students represent an additional manpower input and will be discussed separately. The departments of agriculture have varying definitions of a Research Scientist (Research Officer). In New South Wales a Research Officer is defined as an individual who devotes more than 75% of his time to research, whereas the dividing line used for this paper when discussing the Victorian Department is 50%, although some of what is called research in other departments is regarded in Victoria as service to the industry with a minor research component. However most departments appear to have a definition similar to that used in New South Wales and this is the basis for comparison. The analysis does not include university work relevant to agriculture carried out in faculties other than agriculture and veterinary science, for example: the studies of drought resistance in cereals at Macquarie University; of the biochemical responses to rust infection at the University of Queensland, and of the physiology of transport of photosynthetic products to the developing lupin seed in the University of Western Australia. Although significant in itself the body of work of this nature is not large.

19.1.11 Research in agricultural economics is recognised as being vitally important but is not included in this paper, and in the main allowance has been made in adjusting manpower and other figures. In State departments of agriculture, about 10% of research is in the area of agricultural economics and there is a small but significant effort in this area at universities. It is difficult to assess accurately the magnitude of the research effort in agricultural economics, because of the overlap with marketing extension. More use could perhaps be made by research workers of resources such as the Bureau of Agricultural Economics, to gain an awareness of the possible economic implications of their research programs.

19.2 POLICIES AND AGREEMENTS, AND ORGANISATION OF R&D

19.2.1 The principal organisations involved in agricultural R&D are State departments, CSIRO and universities, with some industry involvement. CSIRO is responsible to the Commonwealth Minister for Science. The statutory basis of CSIRO's activities is the Science and Industry Research Act 1949, and its involvement in agricultural research is based on Section 9(i)(a) which specifies as one of CSIRO's functions the carrying out of scientific research in connection with Australian primary and secondary industries or any other matter referred to the organisation by the Minister. To appreciate fully the relative roles of other organisations and CSIRO, some reference to the historical background is necessary.

19.2.2 The need for a national science organisation to conduct rural research was recognized from the earliest days of Federation, and both the Advisory Council of Science and Industry, which was established in 1916, and the Council for Scientific and Industrial Research (CSIR), which replaced it in 1926, concentrated their research activities on the problems of the agricultural and pastoral industries. The early emphasis upon rural research, which was destined to have a powerful and lasting influence upon the pattern and balance of research in CSIR, and later in the Commonwealth Scientific and Industrial Research Organization (CSIRO), is understandable in view of the overwhelming importance of the agricultural and pastoral industries to the Australian economy in those years, and of the then widely held belief that there were unlimited and profitable markets for rural products. At the time, State departments of agriculture and the universities were limited by staff and facilities in undertaking agricultural research of the magnitude and continuity required, and there was strong support for Commonwealth participation. In the First Annual Report of the CSIR (1927) it is stated that a conference of agricultural experts, called by the Council in March 1927 and including representatives of all State departments of agriculture and several universities,

was of the opinion that, in view of the number and magnitude of the problems concerning the agricultural and live-stock

industries of Australia, Commonwealth participation in agricultural research is desirable; that there are many problems which are national in range or scope and which require concentration, effort and highly specialised equipment for their solution; and that such problems are specially suited for investigation by the Commonwealth.

19.2.3 The States were by no means abrogating their rights to undertake agricultural research, in favour of the Commonwealth. The 1927 Conference recommended that CSIR should undertake investigations 'of a more or less fundamental character' and which are 'national in scope' whereas those 'of a more or less local character' and which 'involve the application of existing knowledge' (i.e. tactical research within the OECD definition) should be undertaken by State departments of agriculture. For example, plant and animal genetics were considered proper research interests for CSIR, but plant and animal breeding were not. In addition the Conference laid great stress on the need for effective collaboration and co-operation with the State departments. To this end a Standing Committee on Agriculture was formed. Its initial role was to act as the 'advisory and consultative body on matters relative to agricultural and livestock research undertaken by the Commonwealth.'

19.2.4 The Australian Agricultural Council consists of the Commonwealth Ministers for Primary Industry and for the Northern Territory, and the respective State Ministers concerned with agriculture. The Council is served by the Standing Committee on Agriculture which is constituted as follows:

the permanent Head of the Commonwealth Department of Primary Industry; the permanent Heads of State departments of agriculture; and representatives from the Departments of Finance, Health, and Northern Territory, Trade and Resources, and CSIRO.

Both bodies are concerned, to a large extent, with regulatory and marketing matters and appear to have a relatively limited role in generating research priorities and policy. The Standing Committee is supported by 14 technical committees, including the Animal Production Committee, the Animal Health Committee, the Horticulture Committee, the Plant Production Committee, Entomology Committee, the Co-ordinating Committee on Agricultural Chemicals, Economics and Marketing Committee, the Vertebrate Pests Committee, the Extension Committee, the Plant Pathology Committee, the Consultative Committee on Exotic Insect Pests, Weeds and Plant Diseases, and the Natural Disasters Committee. These committees are in turn supported by a large number of sub-committees, working parties and expert panels, most of which are formed to investigate and report upon matters of specific concern and are then disbanded. Recognising the importance of communication between research workers, the Council has for many years sponsored a program of technical conferences, and published research newsletters and the Journal of Experimental Agriculture and Animal Husbandry.

19.2.5 The objectives of the State departments of agriculture are to safeguard and improve the productivity of agricultural industries in the States and to encourage the orderly marketing of safe, acceptable produce, with the consequent improvement in the prosperity and quality of life of both rural and urban communities. This mandate involves administration of the State's agriculture under a Minister, with extension, regulatory and research activities. In addition to the central function there is a considerable number of significant but peripheral responsibilities. These may include soil conservation services and educational and other activities. The educational function has been moderated in recent years with, for example, three agricultural colleges in NSW, formerly under Department of Agriculture control, becoming autonomous colleges of advanced education.

19.2.6 An organisational diagram for the NSW Department of Agriculture may be found in the Department's Annual Report of 1975-76; this illustrates the functions just referred to and gives some indication of interactions of the various sections within a State department of agriculture. Each department is responsible for the administration of a large number of Acts on behalf of the State Government, and research may be generated by these regulatory functions as well as by extension activities.

19.2.7 The universities, with the exception of the Australian National University, are State universities with funding derived from the Commonwealth Government on the recommendation of the Universities Commission (now Universities Council as part of the Tertiary Education Commission) which makes recommendations to the Minister for Education. There are faculties of agriculture in NSW (2), Vic (2), Qld, SA, Tas, and WA and faculties of veterinary science in NSW, Qld, Vic, and WA. The objectives of a university are to disseminate existing knowledge and to generate new knowledge through scholarship and research. Faculties of agricultural and veterinary science, however, provide career training and therefore their teaching must, to some extent, accommodate to the needs of the community. Much of their research will be strategic, and even basic research will need to be undertaken within the context of the present or future needs of the industry.

19.2.8 The Rural Industry Research Funds will be referred to under Funding (Section 19.3). These represent agreements between the agricultural production industries and government. Various research organisations contract to do research under these agreements. The major portion of the Commonwealth Extension Services Grant, also referred to below, comprises Commonwealth payments to the States to assist in the further development of extension and regional research services in agreed areas of priority.

19.2.9 There are several agreements involving Australian organisations and research workers assisting developing countries. These are under the auspices of organisations such as the Australian Development Aid Bureau and the Australian Asian Universities Co-operation Scheme. Individual workers are often invited to act as consultants by these organisations and

by overseas bodies. CSIRO devoted \$4.2million of its 1975-76 budget to the 'Centre for Animal Research and Development - Indonesia'. Australia also has bilateral Science and Technology Agreements with the USA, West Germany, India and the USSR. It is envisaged that agricultural research projects would be included under each of these Agreements. In addition, Australia has an understanding on agricultural co-operation with the Peoples' Republic of China and has recently instituted a program of exchange of missions.

19.2.10 There are no formal agreements between organisations conducting agricultural R&D but informal relationships between individual workers and organisations with respect to particular problems do exist. Although some of these arrangements work well, a more effective framework of agreement covering the various sectors contributing to agricultural production research would assist interaction and co-operation.

19.2.11 In discussing organisational relationships, cognisance should also be taken of historical perspectives. In the early part of the 1960's CSIRO was regarded by departments of agriculture and universities with a mixture of resentment, envy and pride despite the substantial concurrent growth in their own funds and facilities. In recent years there have been dramatic changes in the relationship between the State departments and CSIRO and at the present time, with few exceptions, there is a high degree of mutual concern and regard. This has arisen since the States embarked on a program of staff-training and recruitment which has led to an appreciable improvement in the calibre of their research staff and facilities, coupled with regional research policies. A description of typical regional research activity is given in a later section of this chapter (paragraph 19.4.2). The relationships between State departments of agriculture and universities has also shown considerable improvement with the changed attitudes to postgraduate training. Departments of agriculture aspire to have highly-trained research staffs and now encourage staff to undertake masters degrees, generally external; successful people are then provided with the opportunity to undertake PhD training either within Australia or overseas. However the size of the university staffs in most States, and their teaching commitments, militate against meaningful research collaboration in all but a few instances.

19.2.12 Comments made by the OECD Examiners in their report 'Reviews of National Science Policy - Australia' (Paris 1977), relating to the imbalance in research in CSIRO and universities, applies particularly to agricultural and veterinary science faculties because of the large proportion of CSIRO's activities devoted to primary industry research. The Report of the Independent Inquiry into the CSIRO (August, 1977) encouraged a greater degree of co-operation between CSIRO and tertiary institutions and inter alia discussed the siting of some CSIRO activities within universities and espoused the cause of 'Centres of Excellence' raised earlier by the Universities Commission as Special Postgraduate Centres.

19.3 FUNDING

19.3.1 Table 19.1 provides research budgets for 1976-77 for State departments of agriculture and for agricultural production research expenditure by CSIRO, and 1977 research expenditure for agricultural and veterinary faculties in universities. As noted earlier there are some difficulties and assumptions involved in deriving this information. Earlier reference was made to the difficulty of defining a Research Scientist/Officer within a department of agriculture, and although the figures may reflect a more widely based definition than for Research Scientist/Experimental Officer in CSIRO, this is not seen as a serious defect because the aspirations of the State departments for a more highly qualified work force, comparable with that of CSIRO, means that in time the comparison should be valid.

TABLE 19.1

AGRICULTURAL R&D - EXPENDITURE AND MANPOWER 1976-77

<u>Organisation</u>	<u>Budget \$million</u>	<u>% of Total</u>	<u>Manpower No. of Professionals</u>	<u>% of Total</u>
State departments (1976-77)	73.4	56	1572	62
CSIRO (1976-77)	40.4	31	671	27
Universities (1977)	13.0(a)	10	275(b)	11
Private Enterprise (1973-74)	5.0	4	N/A	
	<u>132.1</u>		<u>2518</u>	

(a) See paragraph 19.3.2 for method of calculation. (b) See paragraph 19.3.4 for method of calculation.

These figures are somewhat at variance with those derived from Table 3 of the Industries Assistance Commission (IAC) Report 'Financing Rural Research', where the expenditures for 1973-74 are respectively given as \$49 million for State instrumentalities and \$59 million for Commonwealth departments. However, this may partially reflect different definitions of research and development as opposed to service functions which are research-based. For some time CSIRO has been decreasing its emphasis on agricultural research and the above figures also reflect the sharper definition of agricultural production research used in this paper. Recent changes in CSIRO are associated with the strengthening of fisheries and forest research, the initiation of research on human nutrition, and the strengthening of research on minerals and energy and on the environment.

19.3.2 The total expenditure for faculties of agriculture (\$16million) and veterinary science (\$11million) is \$27million, but this figure is subject to qualification. The universities have a dual undergraduate and postgraduate

teaching function in addition to the research activity of the staff. Funding in the main is on the basis of student numbers with each faculty having an appropriate multiplying factor related to the nature and consequent cost of the teaching programs. Because of teaching and other commitments, the time devoted to research is estimated by staff to be 40% for agriculture and 25% for veterinary science; the lower figure for veterinary science is occasioned by extensive clinical responsibilities. Therefore, of the universities' total recurrent budget for these two types of faculties (\$20.7million) only one-third, or \$6.9million, has been assigned to research. To this must be added outside funds, which amount to \$5.8million, giving a total of \$12.7million. Postgraduate research students, estimated at about 300 (Universities Commission Sixth Report, Chapter 8) make a substantial contribution to research, each one being considered equivalent to one-half an established, full-time, research worker. (Candidates for doctorates in agriculture and forestry outnumber those in veterinary science by more than 3 to 1). At \$4,000 each, their cost is \$1.2million of which half can be attributed to research, the balance being considered to be a teaching cost. The total expenditure on university research is therefore estimated to be \$13.3million. The total expenditure on all activities by State departments of agriculture is \$163million; thus these organisations devoted 45% of their expenditure to research.

19.3.3 The business enterprise expenditure was approximately \$5million in 1974, with a considerable proportion arising from the expenditure of one company which supplies agricultural and veterinary chemicals. The IAC estimate was \$6million in 1973-74 with fisheries and forestry excluded. The difference in the estimates may be due again to difficulties of definition, and there is also evidence of some contraction of effort probably reflecting the financial climate within the rural sector. The above figures may be viewed against an estimated turnover of \$140million for the agricultural chemicals industry (see Submission to Standing Committee of Agriculture by Agricultural and Veterinary Chemicals Association in 1974).

19.3.4 Some reservations also apply to manpower estimates. The total academic staffing in universities' rural faculties is 375 and as indicated above only one-third of the time of staff is devoted to research giving a figure of 125 full-time equivalents. As already stated, each postgraduate student is, in research output, about equal to half an established full-time worker. The 300 postgraduate students are therefore approximately equivalent to 150 full-time workers, and the total university research effort is estimated at 275 full-time equivalent research workers. This figure also shows that more than half the university research in faculties of agricultural science and veterinary science is carried out by postgraduate research students. The research output of the agricultural colleges of advanced education is mainly developmental, with some tactical.

19.3.5 Australia is unique in the extent to which primary producers participate directly in assisting research. The principle of involvement of producers in funding and selection of research is well demonstrated in the operation of the Rural Industry Research Funds (RIRFs). Funds for the 13 statutory RIRFs (including the two fisheries funds) are generally provided on the basis of a producer levy with a matching Commonwealth Government

grant. This source of funding has been the subject of a recent review by the IAC and is covered in detail by a submission from the Commonwealth Department of Primary Industry. In 1976-77, \$31million was distributed for research and of this 52% was allocated to CSIRO, 19% to State departments, 14% to tertiary education institutions, 7% to other organisations, and 8% was allocated to provisions other than research. The CSIRO figure is distorted somewhat by the fact that 70% of the \$18million allocated from Wool Research Trust Fund was assigned to the Organisation. Recently, however, the Government assumed responsibility on a continuing basis for a proportion (60% of that formerly provided by the Trust Fund) of wool research in CSIRO and in the Bureau of Agricultural Economics. The balance of RIRF money amounted to \$13million, of which State departments received approximately \$5million, CSIRO \$3million, and universities \$3million. With the exception of animal production research, the universities are much more dependent on these outside funds than CSIRO. On the one hand this has the real advantage of maintaining a strategic outlook within the universities but, on the other hand, these funds are costly to administer and the degree of dependence in most circumstances has become too great. Another feature is that the funds provided have not kept pace with inflation and this has a disproportionate effect on universities. As well as representatives of the Commonwealth Department of Primary Industry and appropriate producer groups, the committees or advisory bodies which recommend allocations from the funds for approval each year by the Commonwealth Minister for Primary Industry normally also include representatives of the State departments of agriculture, universities and CSIRO.

19.3.6 The Commonwealth Extension Services Grant (CESG) is a non-statutory fund wholly administered within the Commonwealth Department of Primary Industry. In 1976-77 it amounted to \$10million. This allocation is directed primarily to the State departments of agriculture for the purpose of assisting the further development of the States extension and regional research services. On average the CESG contributes about equally to each activity. The Commonwealth Special Research Grant (\$0.2million), which is also administered by the Department of Primary Industry, has as its main purpose the provision of funds on a matching basis for research into those industries not covered by other Commonwealth research funding arrangements.

19.3.7 In addition to the RIRFs, the Commonwealth provides funds under non-statutory arrangements to match industry contributions for research related to barley (\$0.14million), wine (\$0.07million) and honey (\$0.005million). The feasibility of establishing a statutory fund for barley and possibly oats, lupins and other grains, is currently under investigation. The Bureau of Sugar Experiment Stations is responsible for almost all research on sugar cane undertaken in Australia. It derives over 95% of its funds from a levy on the cane crop and in the 1976-77 financial year had a budget of about \$3.0million.

19.3.8 The Australian Research Grants Committee (ARGC) distributed approximately \$10million for 1978 and of this \$0.55million was allocated to agricultural and veterinary projects. The distribution, however, is

uneven, more going to agriculture than veterinary science and, in the former, grants are unequally spread across universities. In the period 1966 to 1977 the real value of the total ARGC grant has not increased despite a doubling of the universities' staff numbers (see 5.3.8, Chapter 5, Volume 1A).

19.3.9 Special research grants from the Australian Universities Commission (and more recently from the Tertiary Education Commission) have increased from about \$2million in 1965 to \$3.5million currently. In real terms, however, the latter sum is equivalent to \$1.5million in 1965 values, and this decrease has taken place in spite of a doubling of staff. Naturally, this affects the availability of research funds in faculties of agriculture and veterinary science.

19.3.10 The Rural Credits Development Fund of the Reserve Bank derives its income from interest on advances against crop payments. In 1977 it distributed \$983,000 for primary production research, principally for projects considered likely to yield short term benefits or for innovative projects which, for various reasons, are not supported by ARGC or RIRFs.

19.4 DESCRIPTION OF MAJOR R&D ESTABLISHMENTS

19.4.1 The organisation of research within State departments of agriculture is on the basis of central and regional research facilities. In NSW, Vic and Qld about half the research activities are carried out in regions. In spite of minor variations, the general principles underlying regional research are similar and only one department is described in detail.

19.4.2 The Victorian Department's organisation of research is discussed with emphasis on regional deployment of research staff; there are three major groups involved in research, the Animal Health Group, the Animal Research Group and the Plant Research Group. The Animal Health Group has six major facilities which are named below, with the number in parentheses being the professional research staff. Two of these, the Veterinary Research Institute (24) and the Attwood Veterinary Research Laboratory (26), are centrally located whilst there are regional Veterinary Laboratories at Hamilton (13), Bendigo (14), Bairnsdale (9) and Benalla (13). In the Animal Research Group there are six facilities all of which are situated outside the metropolitan area. These are the Animal Research Institute (32), the Pastoral Research Institute (14), the Gilbert Chandler Institute of Dairy Technology (18), the Ellinbank Dairy Research Station (10), the Rutherglen Research Station (7) and the Irrigation Research Station at Kyabram (6). The latter two are shared with the Plant Research Group. The Plant Research Group includes ten facilities, three of which are based in the city, these being the Burnley Plant Research Institute (42), the Knoxfield Horticultural Research Institute (25) and the

Vegetable Research Station at Frankston. In the country are the Wheat Research Institute at Horsham (22), the Irrigation Research Institute at Tatura (18), the Horticultural Research Station at Mildura (8), the Tobacco Research Station at Myrtleford (7), the Potato Research Station at Healesville (3) and the Mallee Research Station at Walpeup (3). The varying definition of research workers used by different State departments has already been mentioned. In the Victorian Department, scientific officers who devote more than 50% of their time to research are classified as research staff for the purposes of this paper. Within this definition most of the workers in the Animal Health Group would be excluded. However, some of the Group's work has been generated by its diagnostic and other service functions, and for this reason scientific officers in the Animal Health Group are regarded as part of the over-all research effort. It is germane to note that, although only 12 officers in that group of 99 qualify as research staff within the above definition, 30 research papers were published by the group in 1976-77. Research in the Department originates in a number of ways; about one-fifth of the programs arise centrally and filter down through the organisation and the remainder are initiated at the work face. In the veterinary laboratories, research originates from problems in the diagnostic sphere, from health surveys and from contact with the veterinary profession and producers. Many projects are generated from the ideas, experience and contacts within the field and its literature by staff in both central and regional facilities. There are research advisory committees for a number of establishments and these maintain, and hope to increase, contact with the industry.

19.4.3 The NSW Department of Agriculture has research units in four of its production Divisions (Animal Industries, Dairying, Horticulture and Plant Industry), and a Biological and Chemical Research Institute with 90 research officers at Rydalmere in Sydney, which has major interests in plant pathology and entomology. For organisational purposes the State is divided into five regions, with Regional Directors at Lismore, Tamworth, Orange, Wagga and Yanco. There are, in addition, several towns in the regions where research workers are stationed. The type of research undertaken in regions is generated by the needs of the region, or by emerging problems, and is consequently largely tactical, although the strategic component is increasing; in the main the centrally located research facilities undertake the necessary strategic research together with tactical research which has application in more than one region. Research priorities are decided centrally after consultation between Regional Directors and Divisional Heads.

19.4.4 The essential difference in the Queensland Department of Primary Industries is that, although it has half its research staff distributed throughout the State, there is not the same degree of decentralisation of responsibility. The SA and WA departments are also developing the regional concept, but to a lesser degree. The Tasmanian Department of Agriculture has four-fifths of its research activity outside headquarters.

19.4.5 Agricultural extension in Australia has been dominated, traditionally, by State departments of agriculture which have evolved along broadly similar lines. As the agricultural industries have expanded,

departmental extension services have developed to assist them. Emphasis on the different agricultural industries varies from State to State, and this is reflected in the relative size of their extension service divisions. Extension services cover a broad front of activities, and have a vital role in the implementation of new and improved technologies at the farm level. Extension services also form an important liaison between the producer and the researcher, helping the research services to plan and direct their activities toward the recognised needs of industry. Much effort has been devoted to the development of extension services which operate on a whole-farm basis. Co-ordination of local extension activities is central to this development, and is being assisted by the regionalisation of extension services. It is significant that much of the research conducted by State departments of agriculture is of the 'applied' or developmental type which is directly related to the type of practical farm problems encountered by extension officers. Many regional research projects are designed as part of regional extension programs. The total manpower devoted to extension services by State departments is approximately 1800 (this figure may include personnel who carry out regulatory or other functions in addition to extension).

19.4.6 CSIRO is organised on the basis of research Divisions, the Chief of each one being responsible to the Executive. In some circumstances several Divisions are grouped under a Director or a Chairman. A recommendation of the Independent Inquiry into the CSIRO is that CSIRO be re-arranged so that there are five or six institutes, each with a Director in charge of several Divisions and units. The Divisions with principal interests in agricultural production research, with the total professional staff in parentheses, are Animal Health (90), Animal Production (116), Plant Industry (134), Entomology (116), Horticultural Research (34), Irrigation Research (22), Tropical Crops and Pastures (73) and the Molecular and Cellular Biology Unit (19). Not all these professional staff are involved in agricultural production research; however a number of staff in other Divisions (notably Soils, Land Use Research, Wildlife Research and Environmental Mechanics) are directly involved in research relevant to agricultural production. The total CSIRO effort is summarised in Table 19.2, together with the budgetary provisions for each major category of production.

TABLE 19.2

CSIRO AGRICULTURAL RESEARCH - EXPENDITURE AND MANPOWER

<u>Category</u>	<u>Funds 1976-77(a)</u> <u>\$million</u>	<u>Professional Staff</u> <u>1976(b)</u>
Animal Production	17.37	278
Plant Production	12.10	206
Horticulture	1.67	36
Plant Protection	4.62	73
Resources	4.65	78
Total:	<u>40.41</u>	<u>671</u>

Source: (a) Provided by CSIRO for this paper
(b) 'CSIRO Research Program Objectives 1976'

19.4.7 Research priorities are decided in CSIRO by the Executive after consultation with the Chiefs of Divisions, whose views have usually been formulated after detailed discussion within the Divisions. The CSIRO State Committees were supposed to have some influence in this respect but their impact has been very small indeed. However, at all levels, CSIRO uses a multiplicity of links, both formal and informal, with governments, industry and the community in general, to keep itself in touch with the needs of those whom its research is intended to serve.

19.4.8 There are faculties of agriculture and of veterinary science at a number of universities. The University of New South Wales has a Department of Wool and Pastoral Sciences (10 staff of lecturer status or above) and is concerned with wool technology (outside the scope of this paper) and some work on sheep husbandry. Faculties of agriculture exist at Queensland (23), Adelaide (53), Melbourne (23), Latrobe (13), Western Australia (16), New England (34), Sydney (53), Tasmania (9), and faculties of veterinary science at Melbourne (33), Sydney (58), Queensland (41), Murdoch (19). These faculties are organised either as a series of departments or as a single department in the case of some faculties of agriculture. Research choice is generally made by individual members of staff although there are also elements of leadership and group choice. Rural Industry Research Fund money is an important source of research funds, and it influences the direction and type of a considerable amount of university research. A number of field facilities are used by faculties of agricultural and veterinary science.

19.5 DESCRIPTION OF MAJOR R&D PROGRAMS

19.5.1 The major R&D programs are discussed under five headings: Animal Production, Plant Production, Horticultural Production, Protection of Primary Production and Soils, Water and Land Use. The section on protection of primary production includes some comment on cost-benefit since the IAC Report 'Financing Rural Research' carried out cost-benefit analysis in the field of entomology. Because so much of the research is site-specific, there are several thousand projects in State departments of agriculture and it is not possible to provide other than broad outlines. For CSIRO, considerable detail was already available in divisional submissions to the Independent Inquiry into the CSIRO.

ANIMAL PRODUCTION

19.5.2 About 40% (940 research scientists) of the research effort into agriculture is devoted to studies of animals and pasture production. This figure must be treated with some reserve because of the overlap with other areas, notably crop and animal protection. Contributions of the different research organisations are as follows:

% of all workers in animal research

CSIRO	24
State departments of agriculture	58
Universities	13
Colleges	3
Others	2
	<u>100</u>

The distribution of effort among the various areas of animal research are as follows:

as % of all manpower devoted to
animal research

Pastures and animal production	
including animal nutrition	42
Reproduction	8
Animal breeding and genetics	6
Disease	21
Dairying	15
Pigs and poultry	8

The pastoral industries

19.5.3 The high contribution from industries based on the grazing of extensive grasslands is reflected in the emphasis on research into pastures and animal production in grazing ecosystems; the inputs of research into the intensive animal industries (pigs and poultry) are minor, being about 8% of the total spent on livestock. Research into pasture production in the late 40's and early 50's led to an increase of nearly 20 million hectares in the area of sown pastures during the subsequent two decades. During that period, livestock numbers rose by over 100 million sheep-equivalents, with increases of 60% in the volume of production for wool and over 100% for beef, lamb and mutton. These gains were largely confined to the southern temperate areas of good rainfall, and, since the early 1960's, the emphasis on research in these regions has shifted from pasture establishment and production towards management factors aimed at improving the efficiency of utilisation of pastures by the grazing animal. Although sown pastures, adequately fertilised, are capable of carrying many times more livestock than the native pastures they supplanted, there

still remain nutritional deficiencies associated with large seasonal fluctuations in the quality and quantity of herbage available to the animal during the year, and much research is directed to the means of overcoming these deficiencies. Pasture research in the tropics and sub-tropics is of more recent origin; the potential for increased productivity in the wetter regions is great and the work carries with it implications for many countries beyond Australia. Apart from the high rainfall regions of the north and south, where the greatest potential for animal production exists, there are drier regions of the interior which carry substantial numbers of livestock both domestic and feral. These diverse environments give rise to distinct production problems, and produce a pattern of regional research activities throughout the continent, from the semi-arid interior with livestock as the sole form of production, to cropping-livestock enterprises in the more favourable environment of the coastal regions.

19.5.4 Pastures are the substrate on which the livestock industries exist; they influence animal production through differences in yield, nutritional value and seasonality of production. The diversity of pasture types is great, extending from intensive irrigated areas to extensive semi-arid range-lands. The dependence of animal production on these varied plant communities is reflected in the research activities of CSIRO and all State departments of agriculture, and in the financial support from the wool and meat research trust funds. About 42% of the total research input for animal production is devoted to pastures, grazing management and animal nutrition. These studies cover a broad field, relating to the breeding and introduction of new pasture-plant species and cultivars and their evaluation in plots and under grazing, establishment techniques, plant nutrition, fertiliser use, the development of diagnostic techniques to optimise fertiliser use and the effects of grazing and grazing systems on pasture use, minerals and mineral recycling. There is no single focal point in the search for greater yield. The well-defined mission-oriented program of the CSIRO Division of Tropical Crops and Pastures has as its aim the development of different systems for beef production in all but the arid regions of the north. The program is directed to the integration of studies on the selection and breeding of new pasture varieties with investigations on the nutrition, genetics, physiology and biochemistry of pasture plants, on legume nodulation and on animal nutrition. The work in Qld is augmented to some degree by the University of Queensland and the Department of Primary Industries. This latter organisation, in addition to work on the wetter regions, is concerned with animal production in the native pasture and shrub communities of the interior, seeking principles to guide the balanced use of natural grazing lands. Other State departments and CSIRO are concerned with the effect of grazing on the persistence, and rehabilitation, of native plant communities, and work aimed at monitoring changes in vegetation over time, and with various management treatments, is in progress in many regions of Australia. The NSW Department of Agriculture has an extensive program of pasture research and utilisation at over 20 research centres with about 40 scientists. These numbers may seem large, but considering the diversity of the environment (ranging from sub-tropical to temperate and from wet to arid), the forms of livestock enterprise (dairying to wool), the pasture types - (native and

improved), and the emphasis of the research (legume, grass, fodder crop), it is evident that the resources are spread thinly. Such comments are probably true for all regional research in Australia.

19.5.5 Studies into pasture production in temperate regions are carried out by CSIRO, State departments and universities. In the field of plant breeding and pasture-plant introduction, more progress appears to have been made in extending the boundaries of sown pastures than by improving existing sown species. Many programs need re-appraisal of objectives and methods. In SA there is work on annual Medicago spp., with WA being the main centre for studies on subterranean clover. Problems of toxicity in the native and introduced pasture plants and fodder crops are also being studied. These range from work on poisonous plants and shrubs which cover large areas in Qld, to toxicity of Phalaris tuberosa, lupinosis, rye grass toxicity, and infertility due to clover disease. Work to develop and introduce cultivars of subterranean clover with low plant oestrogen levels are under way, and studies to understand the spread, control and nature of rye grass toxicity, which has caused extensive losses in sheep and cattle, are being carried out at the Waite Agricultural Research Institute, CSIRO and WA Department of Agriculture. With the integration of crops and pastures in many regions there is increased emphasis on the effects of pastures and of grazing management on soil fertility for subsequent crop production. The use of fodder crops and crop residues by livestock is also receiving the additional attention that seems warranted. Fodder conservation practices are also under study in most regions.

19.5.6 Research into tropical and sub-tropical pastures is carried out by the Queensland Department of Primary Industries, by the CSIRO Division of Tropical Crops and Pastures and, to a much smaller extent, by the University of Queensland. The Queensland Department of Primary Industries had an average expenditure of \$1.37million per annum on pasture research between 1974 and 1977. This research covered problems mainly confined to Queensland and included species selection and establishment, production and management practices, pest and disease control, and soil fertility studies. The CSIRO Division of Tropical Crops and Pastures has 27 research workers at the Cunningham Laboratory and 12 research officers distributed among the various regional centres. The NSW Department of Agriculture carries out a large research program into sub-tropical and temperate pastures across 23 research stations employing 39 officers. This research covers establishment methods, soil nutrition, management and utilisation, and weed and pest control. The CSIRO Division of Plant Industry has a large research program on temperate pasture with 22 research workers investigating such aspects as mineral nutrition of legumes, nutrient deficiencies, ecology and production. A lucerne-breeding program is also undertaken by the Division. Research on temperate pastures is being carried out by the departments of agriculture in Victoria, South Australia and Western Australia as well as by the universities in those States. In South Australia 29 scientists are working on problems related to pasture production involving medics, subterranean clover, lucerne and perennial grasses. The research includes studies of seed-coat permeability in relation to self-regeneration, plant nutrition,

pests and diseases, and weed control. A lucerne-breeding program is in progress.

19.5.7 Grazing management studies with beef cattle and sheep are currently directed to the interrelations of stocking rate, genotype, and form of product on the one hand, and plant species, fertiliser application and supplementary feeding practices on the other. These studies, which are an essential part of the integration of management methods for optimum animal production, are represented in most regions with work undertaken by State departments and CSIRO and to a much lesser extent the universities. The results of some of these field studies are being combined with data from the phytotron, animal house and laboratory to develop models as a means of synthesising more efficient production systems (CSIRO; Department of Primary Industries, Queensland; NSW Department of Agriculture). The cattle and sheep population must compete for pasture with mammalian pests, notably the rabbit. The CSIRO Division of Wildlife Research is concerned with these pests and has programs on the biology and ecology of the rabbit, the dingo and the kangaroo, and on the biological control of the rabbit and the management of bird pests. These studies, together with those of the State departments of agriculture and of universities, are necessary to an understanding of the interactions between wild-animal populations in the pastoral regions and the livestock industries.

The nutrition of grazing animals

19.5.8 Sheep and cattle enterprises experience seasonal fluctuation in feed supplies, and, in many areas, livestock production may be impaired for prolonged periods. Studies to define the seasonal fluctuations in the yield and quality of the herbage are being related to the performance of the grazing animal and its nutritional requirements, with the object of developing management and supplementary feeding strategies to minimise production losses. Work in this field is commonly site-specific, and involves regional centres throughout all States, each with its distinct problems. Techniques to estimate the intake and composition of the diet for the grazing animal are also being used to define the qualitative deficiencies of pastures, while studies of intake in relation to the spatial dispersion of the sward are indicating the levels at which production is impaired by the availability of herbage. These studies of the nutrition of the grazing animal in pasture ecosystems need the support of basic work into the nutritional needs of animals and the evaluation of pasture plants and other feeds. Research is being carried out by strong groups in CSIRO, the universities and some State departments. The control of intake by chemical, physical and other mechanisms is being studied in relation to diet composition and digestion, to flow rates through the gut and to the products of digestion. Qualitative studies of nitrogen metabolism have given way to methods designed to measure the nitrogen turnover within the animal in quantitative terms, and models on nitrogen flow through the animal are being developed on the basis of these results. Quantitative estimates of the turnover and use of other metabolites of nutritional significance are also under examination. The requirement for water by sheep and cattle is also receiving attention in relation to environment,

physiological state, electrolyte balance and efficiency of feed use. The protection of plant feeds from degradation in the rumen is under scrutiny as a means of altering the composition and production of milk, body tissues and wool and in relation to the nitrogen economy of the animal. Other studies include the energy evaluation of feeds for ruminants using calorimetry and intermediary metabolism, the energy expenditure of both penned and grazing animals, and the nutrient requirements of sheep and cattle. Research into the metabolism and turnover of both major and trace minerals is being examined in the pen and in the field with emphasis on recycling of minerals in intensive grazing systems, and on the occurrence of mineral deficiencies in animals in relation to continued fertiliser application. CSIRO is developing a strong program in this field which also includes research on the electrochemistry of essential trace elements administered as implants, while the universities and State departments are looking at specific aspects of mineral nutrition. Work is also in progress on the influence of nutrition on body composition and carcass composition, and on the development of methods for estimating accurately the composition of the live animal. These studies are being carried out notably by the University of Sydney, the University of Melbourne and CSIRO. Drought is a recurrent problem of the Australian scene and there is work in progress in all States to look at the biology of undernutrition, basic and practical aspects of drought feeding, and drought management strategies.

19.5.9 Australia has a considerable world reputation in the fields of ruminant nutrition, digestive physiology and wool biology, but the value of this work is more relevant to the hand-fed animal than to cattle and sheep in the field. Australia's livestock population subsists on pasture, and research into animal nutrition has failed to evaluate the nature of the problems which arise in the field. There is a great need to develop techniques to assess the nutritional status of the grazing animal and the production potential of pasture, and such goals can only be achieved by continued contact with the field situation. The wide physical separation of research laboratories from the grazing animal, evident in many areas, is an impediment to real progress. There is a great opportunity for organisations to pool resources in the development of research objectives and positive encouragement should be given in this direction. In this respect the CSIRO Division of Animal Production has already developed initiatives by collaborating widely with other organisations. The work on pastures, grazing management and animal nutrition is presented collectively because of their interdependence (Table 19.3). About 380 scientists are involved in this work.

TABLE 19.3

RESEARCH ON PASTURES, GRAZING MANAGEMENT AND
ANIMAL NUTRITION - MANPOWER 1975-76 (all figures are percentages)

<u>Organisation</u>	<u>Pastures Only</u>	<u>Pasture Utilisation and Management</u>	<u>Nutrition of Penned Sheep and Cattle</u>	<u>Minerals</u>
Commonwealth Government	26	40	17	12
State departments	63	59	58	52
Universities and colleges	11	1	25	36
	<u>100</u>	<u>100</u>	<u>100</u>	<u>100</u>
<u>Type of Research</u>				
Basic	15	15	40	40
Strategic	30	40	40	50
Tactical	55	45	20	10
	<u>100</u>	<u>100</u>	<u>100</u>	<u>100</u>
As Proportion of all Work on Animals	14.0	7.2	18.2	2.7

It will be seen that most of the work is done by State departments (60%), about one quarter by CSIRO and the remainder between universities and colleges. CSIRO and the universities are the main contributors in the basic research fields of physiology of pasture plants and the nutrition of the penned animal in relation to digestive physiology, growth, carcass composition and energy metabolism.

Animal breeding and genetics

19.5.10 The development of animal breeding programs to improve the productivity of cattle, sheep, pigs and poultry is an important input of livestock industries, involving about 6% of the total expenditure on animal research. The CSIRO Division of Animal Production, with a team of 27 research scientists working in this field, represents more than half the national effort. This work is divided between the application of genetics to sheep breeding with reference to wool, meat and reproductive performance, the development of animals adapted to beef production in northern Australia, the development of a breed of dairy cattle capable of adequate performance in tropical climates, and improvement in the efficiency of egg production. In the programs with sheep and cattle, the approach is to select animals which thrive in existing environments, and emphasis is placed on developing indices of genotype responses to environmental effects and on understanding the physiological basis for environmental adaption. The overall thrust is towards the development of animals efficient in the use of resources. The work on sheep and wool examines the effect of specific environmental factors on wool production with the aim of determining their effects on selection procedures.

19.5.11 Much effort is still concentrated on the study of selection flocks, and the theory of selection and flock structure continue to be developed, particularly in relation to non-pedigree flocks. Breeding plans which are likely to improve the economic productivity of sheep include cost-saving attributes such as selection for resistance to internal parasites, fly strike, fleece rot and for ease of shearing. The CSIRO Division of Animal Production has a substantial program on the evaluation of potential methods of wool harvesting and the prevention of fleece rot and fly strike. Basic physiological studies into the special characteristics that enable tropical and desert sheep to produce and reproduce in harsh environments are continuing. At Julia Creek, Queensland, adapted and non-adapted merinos are being studied in relation to production traits; elsewhere in Queensland the Department of Primary Industries is examining breeds of sheep with the capacity to avoid fly strike by shedding fleece from the head, neck, belly and breech. Other work into the genetic control of wool growth and the biochemical genetics of sheep is in progress in CSIRO. The efficiency of meat production in sheep is being studied in relation to reproduction rate, with peri-natal mortalities, drought adaption, frequency of breeding, out-of-season breeding, and twinning rates as selection criteria. The improvement of reproduction rate in Merino sheep, together with the physiological basis for differences in fertility, is being examined by the NSW Department of Agriculture and CSIRO. Breed and crossbreed differences in relation to fertility and meat production are being examined in most States, and work to produce sires for terminal breeding to meet the current marked demands for heavyweight lamb continues. There is still work in progress to establish new breeds, but the rationale behind such an approach is difficult to see. The work on beef cattle involves studies into genetic differences for weight gain and for relative development of tissues that affect growth, and the efficiency of feed conversion to meat by breeds and crosses. In the north the beef cattle program aims at selection for characters which maximise reproduction rate and growth rate, in the face of environmental limitations such as heat, parasites and other diseases, and nutritional fluctuations.

19.5.12 Beef, sheep and dairy sire and breed comparisons are in progress in most States to study relationships between bodyweight and sire, and performance of crossbred progeny and carcass characters. Estimates of the heterosis of crossbred animals are also under way together with studies on the effects of selection among parent breeds on the efficiency of crossbreeding. The evaluation of crossbreeding systems continues in most States, with emphasis in the south on the use of sires of northern European origin for beef production. The development of a dairy breed adapted to tropical conditions continues. Developmental research for the genetic design and organisation of programs for dairy herd improvement in Australia is the subject of a proposal being considered by the Standing Committee on Agriculture. Work in breeding and genetics needs a greater degree of co-ordination to ensure efficient use of resources. This is particularly true in the development of crossbreeding programs and in the selection and evaluation of genotypes in different environments. The research input into breeding and genetics amounts to about 6% of the total manpower in animal research, and it is distributed as follows:

<u>Organisation</u>		<u>Type of Research</u>	
Commonwealth Government	55	Basic	30
State departments	29	Strategic	55
Universities	16	Tactical	15

It is difficult to achieve a high degree of accuracy in this assessment. Some of the research on nutrition and reproduction relates to aspects of breeding and genetics.

Animal reproduction

19.5.13 Efficient reproduction is one of the most direct ways of increasing animal production, yet the record for Australian flocks and herds is variable, despite very considerable research into reproduction since 1950. However, Australian research into reproduction physiology has had considerable impact overseas, especially where sheep and cattle are kept under close control. Studies in reproductive biology are in progress in a large number of institutions. A more fundamental approach is taken by the universities, while applied aspects are under study within the CSIRO and the State departments of agriculture, and this effort is divided more or less equally among the three types of organisation. There is a high degree of co-operation between institutions, a good example being the collaborative effort of the Victorian Department of Agriculture at Werribee, the Reproduction Research Unit of the University of Melbourne and the Medical Centre at Prince Henry's Hospital. Such liaison is also evident in NSW and Western Australia. The major research effort is directed towards the female, in determining the basic endocrine and physiological events controlling the oestrus cycle and pregnancy. The control of the oestrus cycle and synchronisation of oestrus in groups, and the use of embryo transfer techniques (which carry important implications for the rapid multiplication of genetically superior animals) are other fields of endeavour of the University of Sydney and the Victorian Department of Agriculture. The endocrinology of pituitary gland interaction during the oestrus cycle and during pregnancy has led to the development of a specific pregnancy test for sheep (Victorian Department of Agriculture, Universities of Sydney and Melbourne and CSIRO). The seasonal control of reproductive activity is being closely studied at the Waite Agricultural Research Institute, and the anti-fertility effects of oestrogenic clovers are also receiving attention at the University of Adelaide and the South Australian Department of Agriculture. Studies of the male are related to nutritional and metabolic aspects influencing the physiology and biochemistry of semen, and endocrine control of spermatogenesis and metabolic substrates used by spermatozoa. Other work with male reproduction includes physiological responses to climate, effects of trace minerals, and improved techniques for semen storage and use of artificial insemination.

19.5.14 Studies into the reproduction of grazing animals in relation to nutrition, time of mating, frequency of mating, selection for multiple births and grazing management practices are continuing in most States. Successful reproduction involves not only the birth of the young, but also

its survival, and in this respect perinatal losses in the national flocks and herds are high. Work into the physiology of survival, nutrition of the new-born, and the causes and incidence of perinatal mortalities are being pursued. Work on the value of shelter belts, and management practices designed to protect the new-born from extremes of weather, is also in progress. Research into reproductive disorders associated with disease and metabolic disfunction are being pursued by departments of agriculture in all States and by CSIRO. There still appears to be a wide gap between the research and technology going into the study of basic reproductive processes and the problems as they occur in field situations, although progress is being made in the reduction of the gap by CSIRO and university - State department collaboration. There is still room for more liaison in this area. There is little research into the effects of improved nutrition on endocrine functions. About 8% of the research effort on the animal is directed to research on reproduction, made up as follows;

Commonwealth Govt.	21%	Basic	40%
State departments	52%	Strategic	40%
Universities and colleges	27%	Tactical	20%

Animal diseases

19.5.15 This paragraph should be read in conjunction with paragraphs 19.5.55 to 19.5.58, in which entomological aspects of animal health are discussed. The animal population of Australia, although not affected by many of the serious livestock viruses present in other countries, has a continuing burden of disease caused by bacteria, viruses, mycoplasmas, protozoans, worm parasites and plant poisons. Work on animal health involves about one-sixth of the research expenditure of the animal industries. External parasites, particularly cattle tick, lice and biting insects, are also potential transmitters of disease. Australia's vulnerability to the introduction of serious diseases, and their vectors, places emphasis on the need for identification and isolation of virus infections, and the development of control methods. Such research is being carried out by the CSIRO in association with all State departments and health and medical research organisations. Mycoplasma infections, which cause enzootic pneumonia of pigs and respiratory disorders in poultry, are being studied to improve diagnostic techniques and to develop vaccines. There are many diseases in Australia known to lower the reproductive efficiency of farm livestock; these include: vibriosis, trichomoniasis, seminal vesiculitis and dystocia, viral abortion and clover disease. These are being studied by CSIRO, the Universities of Melbourne and Western Australia and State departments of agriculture. Tick-borne fevers, prevalent in the tropical and sub-tropical zones, are being studied with the object of integrating vaccination programs with tick control programs in the control of babesiosis. Work on anaplasmosis is being intensified, with studies on transmission and immunity; CSIRO and the Queensland Department of Primary Industries are major participants in this field. The study of internal parasites aims at better control of sheep and cattle worms with

minimal use of drenches. The work is directed to the ecology of the parasites in the free-living stage, host-parasite relationships, the biology of the parasite and the processes controlling the immunity of the individual animal. CSIRO is the main participant with about 20 research scientists, including those in industry; the universities and CSIRO are also contributing to basic research in parasite ecology and immunology with State departments of agriculture undertaking applied aspects. The control of external parasites, notably the sheep blowfly and the cattle tick; are receiving strong financial and research inputs and are discussed elsewhere in this paper, particularly in paragraphs 19.5.57-58.

19.5.16 Studies of metabolic disorders and their control are in progress in many centres but these do not represent a large input. Bloat control is a problem of some significance that is being studied by CSIRO and the Victorian Department of Agriculture. Plant toxins poisonous to livestock may cause many losses, and are the subject of research in many States. Most departments of agriculture are participating in this research and CSIRO, in association with the universities and State departments, is studying lupinosis, pyrrolizidine alkaloids in numerous plants, Wimmera ryegrass toxicity, and toxicity of Phalaris tuberosa.

19.5.17 Immunity responses in animals, of significance in the development of vaccines, are being studied in the universities and CSIRO with special references to local immunity in the gut (internal parasites and entero-toxaemia), the ontogeny of immunity response and immunopotential. The CSIRO Division of Animal Health has eight research scientists working on internal parasites; major programs include studies of the ecology and control of parasitism in both summer and winter rainfall areas. Some tactical research is undertaken in State departments, and basic research on immunology and on the biochemistry of parasites is undertaken in several university departments, including the Department of Veterinary Pathology at the University of Sydney, which has for many years collaborated closely with the CSIRO McMaster Laboratory and the NSW Department of Agriculture. In the private sector, a number of firms are involved in development work on anthelmintic chemicals. Many of the products originate from the overseas principals of the firms concerned, and there is difficulty in distinguishing between research and development work and promotional activities within Australia. Basic biological research on the ultra-structure and physiology of mycoplasmas and the structural organisation of nucleic acids are being undertaken by CSIRO and the universities to provide a fundamental basis for applied research on virus and mycoplasma diseases. Of the total research into animals, 21% is directed to diseases, parasites and toxic principles, made up as follows:

<u>% Manpower</u>		<u>% Manpower</u>	
Commonwealth Government	22	Basic	25
State departments.	48	Strategic	58
Universities and colleges	18	Tactical	17
Other	12		

The intensive animal industries

19.5.18 Work on pigs is divided about equally between nutrition, health, and breeding and genetics. Most is being carried out by State departments of agriculture, with small contributions from the universities and CSIRO. The nutritional work relates mainly to feed additives, protein quality, supplementation and the evaluation of foodstuffs such as rice, lupins and triticale, and the availability of amino-acids in meat meal, with a small input into the nutrient requirement of reproducing and growing pigs. The main centres of research are the NSW, Victoria and WA Departments of Agriculture, and the Queensland Department of Primary Industries. Health studies are concerned with causes and prevention of perinatal mortalities, parasitic and bacterial infections. Investigations into animal breeding are mainly directed to genetic selection plans, inbreeding and simulated breeding studies. Other inputs relate to carcass evaluation, factors influencing carcass composition (mainly fat content), disposal of piggery waste, and feral pigs as a source of disease. Research in the pig industry appears to operate very much on an *ad hoc* basis, designed mainly to meet the practical needs of the moment. There is little fundamental work on pig biology, breeding, behaviour or efficiency. Neither is there evidence of studies of the ecological implications of pig production. It is unlikely that the problems of the large-scale pig units that are being established in most States are being met by research carried out in Australia, but this type of non-specific research can be 'imported'.

19.5.19 Research into the poultry industry relates to the nutrition and feed efficiency for the production of eggs and chicken meat, with emphasis on nutrient density of the diet, protein and amino-acid evaluation and supplementation, and frequency of feeding. The work is shared equally between State departments and universities. There is also work on the genetics of feed efficiency in meat chickens, the management of parent stock to increase hatchable egg production in the chicken meat industry, and investigation into the problem of leg weaknesses. In the field of egg production the genetics of hybrid vigour are under scrutiny. However, much of the genetic work which is in the hands of the breeder companies is imported from overseas. CSIRO has a program to study the genetics of production characters in poultry. About one-third of the total poultry funding is directed to disease research, with Marek's disease (vaccine development-testing) taking the major share.

19.5.20 An estimate of research inputs for the pig and poultry industries is shown below.

TABLE 19.4
RESEARCH ON PIGS AND POULTRY - MANPOWER 1975-76
(all figures are percentages)

<u>Organisation</u>	<u>Pigs</u>	<u>Poultry</u>
Commonwealth Government	nil	4
State departments	75	77
Universities	11	10
Colleges	14	9
<u>Type of Research</u>		
Basic	5	10
Strategic	45	40
Tactical	50	50
As proportion of all work on animals	3	5

Dairying

19.5.21 Although pasture-based, dairying is a more intensive operation than the sheep and beef cattle industries, it is an industry under extreme economic pressures, with about one-half of the operators subsisting on poverty incomes. The work on pasture introduction and research applies to the dairy industry, except that work on the use of forage crops, and on irrigation and irrigation practice, is more prominent. The biggest problems of the industry at present are in the areas of product pricing, income, and labour utilisation. There is need for more work in the area of labour efficiency of milking, feeding and fodder conservation techniques, and management skills. Apart from pasture production and use, the research fields cover physiology of lactation and reproduction, disease, and management. Other important areas relate to milk quality and mastitis, particularly immunity to staphylococcal mastitis and control measures for the infective organism. More work is also needed into local cellular immunity in the mammary gland. Other topics being studied are the development of tick resistance, teat-skin sanitation, and the physiology of milking with reference to machine milking. In the field of physiology, research into reproduction with special reference to early foetal losses is under way, and work on factors influencing milk composition is in progress. The field of manufacturing research is covered in Chapter 28. Problems of effluent disposal need further attention in relation to pollution problems, particularly for large dairy units where there are heavy concentrations of cows. There is some work on industrial effluent, but more at the farm level. The total research input to dairying is 15% of the total manpower in animal research; this is made up as follows:

	%		%
Commonwealth Government	21	Basic	15
State departments	73	Strategic	50
Universities	6	Tactical	35

Some of this work may overlap with research on pastures, disease, reproduction and genetics.

PLANT PRODUCTION

19.5.22 Plant production is usually considered to include crops, which in 1975-76 occupied approximately 14.5 million hectares, and sown pastures which in 1975-76 occupied approximately 28 million hectares, 1.1 million hectares of which were harvested for seed or cut for hay, green feed or silage. Fruit and vegetables are covered elsewhere in this chapter, and pasture research is covered in the section 'Animal Production' because of the interdependence of pastures with the animals which utilise them. In 1975-76, ten different crop species were grown on at least 30,000 hectares for each, these being wheat, barley, oats, sorghum, sugar cane, sunflower, rice, maize, safflower and cotton. A further ten crops were grown on at least 2,000 hectares these being millet, peanut, soybean, rye, peas, canary grass, rapeseed, linseed, tobacco and navy bean.

Cereals

19.5.23 In 1974-75 the gross values of the traditional cereals, wheat, barley and oats, were \$1,256million, \$275million and \$60million respectively. The equivalent full-time number of personnel working on these cereals in the various research institutions is very difficult to estimate, but is believed to be about 165. The decline in net returns to farmers following domestic inflation and relatively stable export prices for wheat, has resulted in cereal growers seeking to increase production in an attempt to maintain income. This, together with the expansion of the cereal belt to near its outer limit in the late 1960's, has resulted in growers seeking to increase production per hectare, rather than to increase farm size. The major response has been to increase the frequency of cropping, so that rotations have shortened from one crop in three or four years to one crop in two or even two crops in three years. Many of the technical problems have their origins in this change. The establishment and growth of the pasture in the first year after cropping is crucial. When relatively few plants establish after a crop, the annual production may be much lower than from a second year of the same pasture, and, particularly if medics or clovers are only a small proportion of the pasture plants, nitrogen accumulation may be insufficient to maintain levels of soil nitrogen for the frequent crops.

19.5.24 Perhaps the main form of contribution to wheat farming is through the breeding and selection of superior genotypes. Historically,

wheat breeding has been a major contributor to improved cereal farming, and the results from variety trials suggest that its contribution in the next decade is likely to be much greater than in the last two. The relatively recently introduced Interstate Wheat Variety Trials, under the auspices of the Wheat Industry Research Council, are very important in this respect. Breeding often forms an essential link whereby the results of more fundamental investigations (for example of pathology and physiology) are translated into practical application. The Wheat Industry Review Conference (Sydney, 1976) recognised the contribution of breeding to the industry and it resolved that 'This Conference recognises the critical importance of wheat breeding for the industry and takes the view that this activity and associated research should be maintained at least at the present level'. The success of wheat breeding programs is due, in part, to the replacement of expensive technology, for example, foliar fungicides, by the simple introduction of new varieties, for example varieties carrying disease resistance. The wheat industry is the major cropping industry in Australia and its returns form about one-sixth of all farm income. The local industry is highly efficient in comparison with other primary and secondary industries and it is characterised by a high level of managerial skill. This, together with the suitability of wheat for the dry-land farming conditions in Australia, will ensure that it retains its dominant position.

19.5.25 The export earnings of barley in 1974-75 consisted of \$187million (1.8million tonnes) from grain plus \$55million (213,645 tonnes) from malt. Although almost half the Australian production is centered in South Australia, sizeable areas are involved in all mainland States. The estimated number of scientists working on barley in Australia is ten. The main research program is in South Australia where one breeder and one physiologist at the Waite Agricultural Research Institute are supported by a half-time agronomist in the Department of Agriculture; plant pathologists in both organisations assist on a part-time basis with disease resistance problems. This program is the largest cereal-breeding project in Australia and has been responsible for several successful varieties including Clipper which is now recommended for all mainland States. Comprehensive investigations are conducted, including germ-plasm resource, disease resistance, and grain quality, as well as more fundamental research on plant breeding methodology, and the practical development of computer handling of results and field-test mechanisation. The physiological research is unique in Australia and has helped to establish the hormone treatment of grain which is widely used by Australian maltsters. Current work on hormonal control of barley seedling development could find application to field crops, whilst studies on the role of proline in stressed plants may aid breeders to select more drought-resistant varieties. In Victoria the program is staffed by a breeder, an agronomist and a chemist. The latter mainly services the selection program but has tackled some maltsters' problems, including a study of pesticide residue in malt. Western Australia, Queensland and NSW each have a half-time scientist to work on barley improvement, but in NSW only varietal evaluation is undertaken. District agronomists in all three States assist in local variety trials. A national barley collection needs to be established and there is a significant gap in research into grain quality problems involving malt,

animal feed and industrial uses of barley. Research in barley improvement can return considerable dividends. It has been estimated that, in 1974, in South Australia alone the use of the variety Clipper increased the value of the crop by \$14million. The value to Australia would be in the vicinity of \$40million per annum.

19.5.26 Research on barley is not well-organised on an Australia wide basis. The Barley Improvement Plan, operating in South Australia and Victoria since 1957, is supported by contributions from the Australian Barley Board (representing growers in South Australia and Victoria), maltsters and brewers in all States except Western Australia, and from the Commonwealth Government. Allocations for research under the Plan totalled \$228,000 in 1977-78. In Western Australia, a similar contribution arrangement has recently been replaced by a compulsory State levy on barley, oats and lupins delivered to the Grain Pool of WA. Part of these levy funds, together with a Commonwealth Government contribution, is allocated specifically to barley research in that State, with the 1977-78 allocation totalling almost \$119,000. In the Queensland and NSW departments of agriculture, funds used for barley research include an occasional, direct contribution from the State barley marketing authorities. The feasibility of establishing a scheme along the lines of existing statutory Rural Industry Research Funds to support research into barley on a national basis is currently under consideration.

19.5.27 Oats is an important on-farm stock feed, and a small export trade exists. Improvement programs are carried out by one full-time breeder at Temora, NSW, and by two half-time breeders in Western Australia and South Australia with support from cereal agronomists for variety trials. These programs could be strengthened since recent overseas studies have demonstrated a considerable potential for increased yield following interspecific hybridisation with other *Avena* species. Recent figures from the Western Australian Department of Agriculture put the cost of its oat program at \$50,000 per year, but the return to farmers from a newly released variety was conservatively estimated to be \$1.2million per year.

Oil-seeds

19.5.28 Five oil-seed crops are grown specifically in Australia for their oil, or meal and oil; these are: sunflower, safflower, soybeans, rapeseed and linseed, while oil is also derived from crops grown for other reasons, namely cotton, peanuts and maize. At the Australian Oilseeds and Protein Grains Research Conference held at Toowoomba, Qld, in October 1976, research priorities were listed for the various oil-seed crops. Such an exercise is a very valuable one and can assist in correctly directing future research. Thus a strategy is recommended for other groups of crops. All State departments of agriculture have programs dealing with various oil-seed crops, as have the CSIRO Divisions of Plant Industry, of Tropical Crops and Pastures, and of Irrigation Research, and the University of Queensland. The common areas of research are disease resistance; weed problems; agronomic practices such as time, rate and method of sowing; and variety testing, along with breeding, for oil quality characteristics.

Such characteristics include low erucic acid in rapeseed oil, and higher and lower linoleic acid in rapeseed and sunflower oil. There is a distinct possibility of overlap of research effort in the oil-seed crops; however, continuity of such activities as the Toowoomba Conference mentioned above, and the introduction in November 1977 of the Statutory Oilseeds Research Scheme, should guard against this. As an example of the research effort in this area the Queensland Department of Primary Industries is carrying out 15 projects dealing with oil-seed crops. The manpower of the national research program is estimated to be of the order of 40 to 50.

Grain legumes

19.5.29 Because plant seed protein is much cheaper to produce, and is more easily stored, than animal protein, increased attention is currently being paid to grain legumes. The aims of the Australian grain legume program are: to find an alternative cash crop to cereals that is suitable for inclusion in a rotation; to provide protein concentrate for intensive animal production; to supplement the range of edible oils; and to provide a potential source for meat substitutes. Research can be divided into that on tropical grain legumes such as navy bean, peanut and cowpea, and that on the temperate legume, broad bean. The former group is concentrated in Queensland and northern NSW and the latter in southern Australia. The work mainly involves yield comparisons of genotypes between seasons and sites and under varying cultural treatments, e.g. plant density, time of sowing, fertiliser application and irrigation management. Disease resistance and disease control are also investigated. Field research is supplemented by some physiological and biochemical studies. A total of about 50 workers is widely spread between CSIRO, the Universities of Queensland, Sydney, Melbourne, Adelaide and Western Australia and (with by far the largest numbers) State departments of agriculture. The program is not co-ordinated and there is little doubt that progress would be greatly accelerated by a co-operative program of yield-evaluation over say five years and across a range of environments in all States. The introduction and breeding of lupins at the University of Western Australia is an excellent example of the impact one scientist can have on developing a plant species to economic importance in an agro-climatic region.

Sorghum

19.5.30 Sorghum, during the 1970's, has developed into an important crop with 0.75million tonnes, worth approximately \$35million, exported in 1974-75. The total Australian crop is raised on approximately 0.5million hectares with a production of 0.9million tonnes, 70% of which comes from Queensland. The Queensland Department of Primary Industries estimated an expenditure of \$113,000 on research concerned with sorghum in 1974-75. Most of these monies were used in a breeding and evaluation program staffed by one breeder assisted, on a part-time basis, by agronomists and plant pathologists (equivalent to one additional person) of the Department and of the University of Queensland. The involvement of commercial seed firms, in introducing varieties and hybrids from the USA and in producing

local hybrids, is also an important aspect of sorghum production. Breeding and agronomic work is also undertaken by the CSIRO Division of Tropical Crops and Pastures with two physiologist-agronomists working in Queensland and one breeder at the Kimberley Research Station. The aim of the latter is to produce dwarf lines adapted to the tropics and suitable for mechanical harvesting. The potential for sorghum across northern Australia is high.

Sugar cane

19.5.31 The value of the Australian sugar cane crop has varied in the last 10 years from \$180million to \$710million depending on world prices. Nearly all the crop is grown in Queensland with only 3% grown in NSW. The Ord River region is potentially a locality for sugar cultivation. All the research is undertaken by the Bureau of Sugar Experiment Stations with about 18 senior research staff. The Bureau is primarily financed by growers and sugarmill organisations, with some contribution from the Queensland Government. Research has been mainly concerned with irrigation frequency, salt tolerance, drainage, time of harvesting, density of plants, fertilisers, disease and pest control and breeding. The professional research staff consists of eight involved in soils and agronomy, seven in entomology and pathology, and three in breeding. Key issues in production are rising costs, the low domestic price of sugar, inefficiencies in harvesting systems, inadequate drainage of crops, and diseases and pests. Despite these an increase in production from 2.75 to 3.25million tonnes occurred between 1975 and 1976, part of which may have been seasonal.

Rice

19.5.32 The Murrumbidgee and Murray Valleys of south western NSW are the largest rice growing areas in Australia, with a smaller area in the Burdekin Valley of Queensland. The crop is comprehensively serviced by a team of scientists, employed by the NSW Department of Agriculture, stationed at Yanco. Two breeders and one physiologist-agronomist work full-time on the crop and are supported on a part-time basis by two cereal chemists and a plant pathologist. The aim of the program is the production of high-yielding rice varieties with good grain quality, the investigation of rice growing problems and pure seed production. The program maintains close co-operation with the Rice Marketing Board. The integrated team approach to a single crop in a specific agro-climatic area has been particularly successful in improving the yield and quality of the rice crop. In recent years rice variety evaluation has been carried out by the Queensland Department of Primary Industries in the Burdekin Valley, which is considered a potential area for a large rice growing industry. The agronomic and economic feasibility of rice growing in the Ord Valley has been under investigation at the Kimberley Research Station. Such a major possibility is dependent upon the outcome of the application of the existing agronomic information to the particular environmental conditions and the economic investigations into transport and marketing aspects of the crop.

Maize

19.5.33 At present maize is of minor importance in Australian agriculture; the area sown is approximately 10% of that for grain sorghum. Both the Queensland Department of Primary Industries and the NSW Department of Agriculture conduct improvement programs, the former costing approximately \$100,000 in 1974-75. At the Kairi Research Station, one breeder is producing lines to fit the various agro-climatic areas of tropical Queensland; introduced commercial material is not applicable to this region. At the Grafton Research Station one breeder-agronomist is producing hybrids for the NSW coastal areas and is supported by an agronomist working about one-third time on this topic at the Glen Innes Research Station. District agronomists in both States conduct trials of local and introduced hybrids, and commercial seed firms are also involved in the promotion of introduced material. In addition one member of the University of Sydney's Plant Breeding Institute devotes about a quarter-time to maize studies and the development of lines with improved nutritional value.

Cotton

19.5.34 Research on cotton, which is grown mainly in NSW, with about one-sixth of the crop in Queensland, is conducted by the CSIRO Division of Plant Industry Cotton Research Unit (six scientists) based at the NSW Department of Agriculture's Research Station at Narrabri, by the staff of that Research Station, and by the Queensland Department of Primary Industries. The research is primarily aimed at reducing losses by pests, including Heliothis spp. by biological control and by breeding resistant cultivars.

Tobacco

19.5.35 Tobacco in Australia is grown mainly in Queensland (54%) with smaller amounts in Victoria (35%) and NSW (11%) and these States provide approximately 50% of Australia's needs. Research is now carried out in Queensland and Victoria, the latter involving 13 scientific officers at the Tobacco Research Station, Myrtleford.

Rye

19.5.36 Cereal rye production can be expected to increase in Australia in order to replace the present importation of the grain. Very little research is done on rye in Australia. A breeding program at the University of New England is, however, noteworthy. Large areas of South Australia are traditionally regarded as suitable for rye growing and a modest increase in this crop is clearly warranted. This hardy species could move the cereal growing a little further into the marginal areas.

19.5.37 There are six Australian programs on the man-made cereal crop, Triticale, which is a cross between wheat and rye. Of these, the breeding and selection programs being undertaken by the Victorian Department of Agriculture at Werribee and by the Waite Agricultural Research Institute

comprise the major inputs. The Departments of Agriculture in NSW and WA are carrying out limited field testing while the work of the University of Sydney is mainly on cytological aspects. Estimated full-time research worker equivalents engaged on Triticale work in 1976-77 were 3.5. Interest in this new crop stems from its potential for high grain yield under marginal conditions, its expected wide range in disease resistance, and its high quality protein, which may make it a useful feed grain. Uses for human food may develop at a later time; however, at present, its future as a commercial crop in Australia appears to be dependent primarily on the price it will attract as a feed grain. This potential new crop also serves as an example of the use of intergeneric hybridisation in plant improvement. Synthesis of entire genomes, and the transfer of parts of a genome to a conventional species, appears to be a promising procedure for broadening the basis of disease resistance. This line of research emphasises the need for pathologists to work in collaboration with cytogeneticists and breeders.

19.5.38 Australia imports about \$1million worth of mint oils per year, and efforts are being made by the Tasmanian Department of Agriculture to establish mint growing. Efforts are also being made to establish an industry to supply solasodine as a precursor for cortico-steroid drugs. These are of major importance in medicine and their annual retail value in Australia is estimated to be in the order of \$20million. At present all is imported. Surveys of alkaloid content have been made of a number of Solanum species, and limited field trials are being undertaken in eastern States and South Australia.

19.5.39 From the information available the following estimates of professional manpower are made with respect to research in fields concerned with plant production:

Traditional cereals	165
Oil-seeds and protein grains	100
Sorghum, sugar cane, rice, maize, cotton	35
Pastures	150
Other plant species	18
Basic plant studies	55
Biometrics (other than service)	20
	<u>543</u>

It is stressed that the figures are estimates only, and that they may differ from other estimates for several reasons, including differences in categorisation of research program goals. The total represents about one-fifth of the total research effort on agriculture, and a little more than half that involved in animal production.

19.5.40 Fundamental studies of plant production are carried out mainly in the CSIRO Division of Plant Industry. These involve research in plant biochemistry to increase understanding of the mechanisms of the regulation of the metabolic processes responsible for photosynthesis (10

proportionally-qualified researchers), nitrogen fixation (8) and storage of proteins and lipids in seeds (9). Australia is noted for its work on the biochemistry, biology and microbial ecology of nitrogen fixation by legumes; as well as CSIRO, the universities in Western Australia (4) and the Waite Agricultural Research Institute (2) are making notable contributions. Plant physiology work in CSIRO is concerned with the physiological basis of plant growth and the development of yield in wheat (11), and also with the role of the pigment phytochrome with respect to flower initiation. Other studies in universities are concerned with mechanisms of nutrient uptake (3), effects of stress, water and salt, on cereals (3), the development of yield (3) and the role of growth hormones (3). Current projects in the CSIRO Division of Plant Industry in the field of plant chemotherapy, plant disease resistance, and epidemiology (15) are concerned with the synthesis and biological properties of a group of compounds regulating plant growth and structure-activity studies and biological evaluation of a series of systemic fungicides. The University of Sydney is concerned with carbohydrate and nitrogen metabolism in plants (2) and nitrogen fixation (1). There may be another 5 staff in the universities working on fundamental aspects of animal and plant metabolism that are relevant to this review.

19.5.41 One of the major problems in plant breeding is the understanding, and quantitative evaluation, of the interaction between the genotype and the environment. Although methods already exist for its investigation, it is an important topic of biometrical research in some Australian universities and has also been important within the CSIRO Division of Mathematics and Statistics. Historically, problems in plant breeding research have been a major spur to biometrical research, but of course this is much wider now. Biometrical activity involves a large component of service work to various laboratories and especially to field studies. In the past, the CSIRO Division just mentioned has been particularly important in consulting and service work, but this area is now given less emphasis. About one-third (23) of the staff of the Division are involved in consulting work relevant to rural research and about 10 are concerned with research pertaining to rural sciences. In the universities, approximately six professional staff contribute to research in biometry. In addition to academic and research organisations, State departments of agriculture contain an appreciable number of biometricians (60). The Queensland department has 20, and this staff has both theoretical and practical strength, as is also the case in NSW (15). In the other States, though a biometrical service is provided, it tends to be on a smaller scale. For example, in South Australia, the Biometrics Unit in the State Department of Agriculture employs about six graduates, all with computing as well as statistical qualifications. While important biological research is conducted in the State departments (such as the animal genetics work in the NSW Department), the biometrical input is mostly of a service nature with a minor (five staff) research contribution.

HORTICULTURAL PRODUCTION

19.5.42 Horticulture here includes fruit and vegetable production, landscaping and nurseries, but excludes post-harvest handling (considered in Chapter 28), and protection (considered elsewhere in this Chapter). Three quarters of horticultural research workers in Australia are employed by State departments of agriculture. Organisations other than those shown in Table 19.5 contribute to horticultural research to a small extent. There is a minor contribution from private industry, occurring mostly in field testing and promotion of agricultural chemicals and equipment. For example, CSR Ltd operates about 500 hectares of macadamia nut orchards in southern Queensland; technical and developmental research associated with horticultural aspects of the culture of this new crop are conducted by one graduate member of staff, and entomological problems are investigated by another. Numbers of research workers have been calculated as full-time equivalents by weighting for multiple duties (research, extension, teaching, administration) with one-half allowed for advanced graduate students.

TABLE 19.5

HORTICULTURAL RESEARCH - MANPOWER

	<u>Total Agricultural Research Workers</u>	<u>Horticultural Research Workers</u>
CSIRO	671	27
State departments of agriculture	1572	156
Universities and colleges	<u>275</u>	<u>24</u>
Total:	<u>2518</u>	<u>207</u>

There are 32 regional horticultural stations or laboratories of the State departments more or less evenly distributed between the States, and CSIRO laboratories at Griffith and Merbein.

19.5.43 The numbers of horticultural research workers in State departments as a proportion of the total agricultural research workers is 8%. This is lower than the gross value of horticulture as a proportion of the total value of agriculture in Australia (15%), but the calculated number of research workers excludes those studying problems of handling and protection. The cost of horticultural research is difficult to calculate, but if 207 workers are each responsible for an expenditure of \$60,000 the total is about \$12million or 1.3% of the gross value of this production. The distribution of research workers by crop reveals a notable paucity of research workers on ornamentals. Though the gross value of this production is extremely difficult to calculate (statistical returns do not allow for all categories of floriculture, ornamentals, nurseries, landscaping, gardens, playing fields, etc.), it is clear that there is little research; that which is done was started within the last ten years.

Although there is an adequate proportion of researchers working on horticulture, there are serious deficiencies and imbalances in the research undertaken. Australian universities have 6 staff of lecturer status or above in horticulture (c.f. total staff of 375 in rural sciences) which means that universities have a poor capacity to cope with postgraduate training in horticulture of students from within Australia and from developing countries where horticultural crops are of major importance. (The 24 workers for universities and colleges shown in Table 19.6 are mainly postgraduate research students). The approximate number of horticultural R&D workers, calculated as full-time equivalents, in different crops and different organisations (with one half allowed for postgraduate research students) is shown in Table 19.6.

TABLE 19.6

HORTICULTURAL RESEARCH - GROSS VALUE OF DIFFERENT CROPS, AND RESEARCH MANPOWER

<u>Crop Group</u>	<u>Gross Value</u> <u>1976-77</u> <u>\$million</u>	<u>Manpower</u>		
		<u>Cwlth</u>	<u>State</u>	<u>Universities and Colleges</u>
Tropicals	)	2	11	1
Citrus and sub-tropicals	) 294	6	25	4
Temperate and soft	)	7	53	6
Vines	123	10	18	6
Vegetables	290	1	46	5
Ornamentals	200	1	3	2

19.5.44 Compared with other countries Australia's horticultural research has a reasonable base in fundamental work, but some weaknesses in development and extension. This is not due so much to deficiencies in personnel, but to defects in communication due to the fragmentation which exists in the organisation of horticultural research. Due to the large number of crops, the generally small (though labour-intensive) holdings and the wide array of problems, the research topics are individually small and diverse. For example, the Australian Research Newsletters list over 1000 projects (942 for horticulture in 1976 and 208 for vegetables in 1974). Three topics have been chosen to illustrate the type of research undertaken.

Fruit growth studies

19.5.45 This is an area of research of long standing due to the history of research associated with fruit storage (MacAlpine, the first agricultural scientist employed in Australia, worked on Bitter Pit in apples). Though the motivation was fruit storage and handling, prompted by export sales, many of the problems have been difficult to solve and have led to basic studies of fruit development, at present being carried out in four laboratories.

CSIRO Division of Horticultural Research	sugar and acid metabolism in grapes
CSIRO Division of Food Research	hormone control of tomato fruit growth
Waite Agricultural Research Institute	hormone control, growth in <u>Vitis</u> and <u>Prunus</u> fruits sugar accumulation by grape berries
Victorian Department of Agriculture, Tatura	hormone control of growth in fruits of <u>Prunus</u> .

Some practical application has resulted from these programs but many problems remain and justify their continuation.

Vine improvement

19.5.46 Grapes continue to be one of Australia's most important crops and there has been intense activity in vine improvement in all areas. The coincident activity is due partly to new methods but also to a 'follow-the-leader' attitude. Though some adaptive and testing work is needed, much of it is common and co-ordination should produce more results with less effort. Fortunately, in this instance, a Vine Improvement Committee was organised under the aegis of CSIRO. This provides opportunities to co-ordinate such matters as clonal selection, breeding, root-stocks, virus diseases and variety testing methods.

Orchard design

19.5.47 There is increasing evidence from overseas, and within Australia, that traditional tree size, shape and spacing may not be the most productive and profitable. There is Australia-wide interest in achieving optimum orchard design through varying rootstock, spacing and tree form, bearing in mind the need to also concentrate on fewer varieties than are grown at present. In the case of apple, rootstocks per se have been under study for the longest period. Many trials have been concluded but long term experiments remain at Orange, Bathurst, Lenswood and Donnybrook. More recently, tree densities are being compared, with emphasis on close spacing, alone or in combination with root-stocks. Such trials exist at Stanthorpe, Orange, Tatura, Scoresby, Stanley, Lenswood, Merbein, Stoneville, Manjimup and Donnybrook. Such experiments are long term and have a high labour requirement for management and annual recording; space limitation dictates that the number of comparisons in any one trial is relatively small; there is lack of co-ordination in the choice of comparison to be made and each experiment is independently designed. Results are only applicable to the site and cultural conditions of the experiment with no means available for extrapolation to other growing conditions. It is obviously not possible to conduct such trials in each area

for which the information is required. It thus appears necessary for such topics to be tackled co-operatively on a national scale, using experiments designed to detect principles which could then be used for extrapolation and prediction.

PROTECTION

19.5.48 Protection research deals with safeguarding crops and livestock from pests and diseases and additionally from competition from other life forms. It is customary to divide protection research into a number of more or less distinct sub-areas: crop pathology (plant diseases caused by micro-organisms including nematodes and viruses); crop entomology and acarology (most invertebrate pests); forest pathology; forest entomology; vertebrate pests (dingoes, rabbits, rats, mice, birds); veterinary pathology (livestock diseases and internal parasites); veterinary entomology and acarology (external parasites of livestock); weeds; and plant breeding for resistance to pathogens and insects. All the topics listed have been included in this section with the exception of the diseases and internal parasites of livestock; forest pathology and entomology have been included because in some instances it was not possible to separate expenditure or manpower devoted to these programs. The value of protection research must be measured, in the final analysis, by the value of what is protected, the cost of protection, and the degree to which protection is needed and is successful. Financial data have provided the main yardsticks. Many sources were consulted, and the season 1974-75 was chosen as a base year because it is the most recent year for which full details are available.

19.5.49 The largest single expenditure on protection research is by CSIRO. In 1974-75, CSIRO devoted about 8% of its total expenditure to protection research, i.e. about 12½% of the total agricultural production R&D expenditure for that year. A remarkable feature of this expenditure is that it is dominated by entomology (64%) and represents surprisingly little plant pathology (perhaps 10%). Total expenditure by State departments was \$9.1million.

TABLE 19.7

PROTECTION RESEARCH - EXPENDITURE 1974-75

	\$million	Percentage of total
CSIRO (a)	8.2	39.2
NSW Department of Agriculture	2.6	
Victorian Department of Agriculture	2.5	
Queensland Department of Primary Industries	1.8	
All other Departments of Agriculture (b)	2.2	
All State Departments	9.1	43.5
Waite Agricultural Research Institute	0.67	
University of Sydney	0.30	
University of Queensland	0.15	
All other universities	0.25	
All universities	1.37	6.5
State Forestry Commissions	0.25	1.2
Business Enterprises	<u>2.0</u>	<u>9.6</u>
Grand Total	<u>20.92</u>	<u>100.00</u>

(a) This figure has been estimated from CSIRO Annual Reports, and is nearly twice the 1976-77 figure provided by CSIRO for this chapter (\$4.62 million, Table 19.2). The difficulties in assessing CSIRO expenditure on agricultural production research are mentioned in 19.3.1.

(b) Including Northern Territory and Bureau of Sugar Experiment Stations.

Business concerns contribute mainly developmental research, testing chemical compounds for their potential marketability in Australia. The total for commercial interests was calculated to be nearly 10% of the national total, but the extent to which this figure should be discounted in view of the promotional aspects of much of the commercial research is an open question. The next in expenditure on protection research would be the Waite Agricultural Research Institute which has departments of plant pathology (nine professionals) and of entomology (eight).

19.5.50 Membership lists of professional societies record at least 550 entomologists and 300 plant pathologists in Australia, but many of these would have only a peripheral involvement in agricultural R&D. Many entomologists in tertiary institutions would have had no significant involvement with agricultural research.

19.5.51 Detailed analysis of research expenditures is difficult although figures for disciplinary areas, for 1974-75, have been calculated for four organisations, which together account for about 70% of the total, namely CSIRO, NSW and WA Departments of Agriculture, and the Queensland Department of Primary Industries. This analysis is set out in Table 19.8.

TABLE 19.8

PROTECTION RESEARCH
EXPENDITURE ON DIFFERENT RESEARCH DISCIPLINES, 1974-75

<u>Industry</u>	<u>Discipline</u>	<u>Research Expenditure</u>	
		<u>\$million</u>	<u>% of total</u>
Livestock	External parasites	2.9	21
	Vertebrate pests (mainly as competitors for pasture)	0.7	5
Cropping	Insect pests	2.7	20
	Plant pathogens	2.3	17
	Nematodes	0.2	1.3
	Breeding for resistance(a)	0.7	5
Trees and timber	Forest insects and pathogens	0.2	1.3
General	Weeds (about two thirds in pastures, one third in crops)	1.0	7
	Biological control (b)	0.5	4
	Ecological effects of pesticides	0.2	1.3
	Taxonomy and basic research	1.4	10
Stored products		0.5	4
Domestic pests(c)		0.4	3
Total:		<u>13.7</u>	<u>100.0</u>

(a) Assuming that half of the plant breeding programs are concerned with resistance to insects and disease.

(b) Dung control (CSIRO) and a variety of other projects.

(c) Bush flies, houseflies, mosquitoes, ants, etc.

19.5.52 Total expenditure on protection research was \$20million in 1974-75 and is now probably well over \$25million per annum. In its submission to the Industries Assistance Commission (IAC) report 'Financing Rural Research', the CSIRO Division of Entomology was able to project figures indicating a benefit-cost ratio of about two (for research from 1960

to 1975 and benefits extending to the year 2000 at a 10% discount rate) approximating an internal rate of return of 20%. But, as the IAC pointed out, the benefit was derived primarily from a relatively small number of the total projects undertaken; other projects were profitable, but to a much lesser extent. In other words, benefit-cost analyses for mid- to long-term research can only indicate, in a general way, which lines of research may prove most profitable; they should not be used in isolation as a guide to investment in research. Another kind of analysis, also attempted by the IAC, was to compare amounts spent on rural research with the value of the particular commodity concerned. This is an attractive proposition at first sight, especially as the cash benefit of protection research can only be determined in relation to the financial return from the commodity protected, but there are serious drawbacks in attempting such a comparison. It is not so much the total value of the commodity that is relevant as the value at hazard, and in many instances the proportion at hazard is literally 'anybody's guess'.

19.5.53 There is a fallacy in assuming that the amount of protection research should relate directly to the cash value of the produce protected, for the difficulty of protection is also relevant. There is no point in doing more research on a problem once it has been solved, however great the cash return from the solution. However, in some industries with intractable pest problems (examples will be dealt with elsewhere), continued research is necessary to keep the industries profitable at all, even though research cost in such industries may seem disproportionately high.

19.5.54 Irrespective of the problems of how one should interpret amounts spent on the protection of different commodities, the basic data seldom exist. Even in data carefully investigated by the Bureau of Agricultural Economics, the cost attributable to application of pesticides, for instance, is often compounded with other labour costs.

19.5.55 The rural industries in which costs of pests probably have been most comprehensively analysed are the sheep and cattle industries. For these, the relation of gross product to production cost, protection cost, pest losses and research expenditure is attempted in Table 19.9 below. It must be stressed, however, that these figures are approximate, and take account only of blowflies and other external parasites on sheep, and ticks on cattle, and exclude the cost and value of research on, for example, weed competition in pastures, dung dispersal by biological control, and pests and diseases of forage crops.

TABLE 19.9

COST OF PROTECTION OF LIVESTOCK FROM EXTERNAL
ARTHROPOD PARASITES 1972-73 (all values in \$million)(a)

	<u>Sheep Industry</u>	<u>Cattle Industry</u>
Value of products	1,551	1,539
Estimated cost of production(b)	682	877
Losses from external parasites (including blowfly on sheep)	20.5	26.8
Cost of control measures	16.2	13.9
Total cost of pests:	<u>36.7</u>	<u>40.7</u>
Cost of pests as % value of production	2.4	2.6
Cost of pests as % cost of production	5.4	4.6
Cost of research (\$million)(c)	0.7	1.3
Cost of research as % value of production	0.05	0.08
Cost of research as % cost of pests	1.9	3.2

(a) Data mostly supplied by Bureau of Agricultural Economics; other data taken from 'Cattle Tick in Australia', Cattle Tick Control Commission, 1973.

(b) Approximate cost: return ratio on sheep-dominated properties of 0.44, and on cattle-dominated properties of 0.57; data from 'Australian Grazing Industry Survey, 1973-74', Bureau of Agricultural Economics, 1976.

(c) Estimated on the basis of costs in 1974-75.

19.5.56 As mentioned above, another possible comparison would be between the value of the proportion of a crop at hazard and the cost of the research to insure against such a loss. Such estimates should be attempted in any relevant research institution that has to plan its research budget, or by any industry-based funding body that allocates research grants; yet these estimates are of such a subjective nature that it would seem inappropriate to tabulate them; and a number of commodities are therefore discussed separately below.

Sheep

19.5.57 The major problem is blowfly strike. Control measures include mulesing and crutching (control of breech strike only), and jetting with insecticide. If none of these measures was carried out, losses of young sheep would perhaps vary between 25% in a good year to over 75% in bad years. Mulesing and crutching are expensive in labour and probably would not be employed if chemical control were more effective. Jetting is a relatively simple exercise, but blowflies have become successively resistant to the insecticides previously used. Although the industry still has several organophosphorus compounds which are environmentally acceptable and achieve a measure of control, there is an urgent need for new approaches to the control of blowfly, with several hundred million dollars worth of the annual output of the sheep industry at hazard. Current research into methods of 'chemical mulesing' is one such approach.

19.5.58 In southern Australia, foot-rot is also an important problem for the sheep industry. The labour-intensive control measures in use today were developed more than 30 years ago after the causal organism had been isolated. Treatment consists of the inspection of hooves, followed by paring and foot-bathing. This must be repeated at intervals, with no certainty that the disease will be eliminated from the stock. Recent developments show promise for improved control, and there is need for an accelerated research program aimed at reducing losses, which currently total several million dollars annually.

Cattle

19.5.59 The most serious pest problems are associated with cattle ticks. Chemical control does not appear promising in the long-term because of the ability of the ticks to develop resistance. The most promising strategy is the use, in breeding programs, of Bos indicus cattle that have a degree of natural resistance to the ticks. However, there is a problem in persuading cattlemen to accept the new breeds, and, meanwhile, losses attributable to ticks and tick-borne fevers are equivalent to more than 2% of the gross value of cattle.

Cereals

19.5.60 Field problems are mainly caused by pathogens (wheat stem rust is one of the most serious) and weeds. Together, these probably are capable of halving the potential yield. Current research on rust in NSW and Queensland is highly regarded, but has concentrated on incorporating resistance genes in one cultivar. It is well-known that the resistance of single cultivars may break down due to the emergence of counteractive strains of pathogens in the field, and a new approach, the use of 'multilines', where resistance genes are scattered through individual plants of an otherwise uniform crop, needs to be pursued. Pre- and post-emergence sprays are effective for some weeds, but the most satisfactory long-term method is integrated control, incorporating chemical, biological and management methods. Only a fraction of the possibilities has so far been investigated.

Field crops and vegetables

19.5.61 Some field crops, such as cotton, are exceedingly vulnerable to insects, and can be grown only under a continuous umbrella of protection with pesticides; but continual exposure to pesticides causes the development of resistant strains of insects (this was a significant factor in the decision to abandon cotton growing in the Ord River area). Overall, field crops are probably 30% at hazard from insects, pathogens and competition from weeds. Wherever attacks are experienced over a large area, there is a temptation to seek economies of scale by using aircraft or other large mechanised spraying systems. This expedient usually heralds the beginning of the end of reliable chemical control, and what is required is a pest-management approach. As in the case of cereal production, some weeds can be controlled by chemicals, but integrated control is a better long-term solution.

Orchard fruit

19.5.62 In any analysis of protection research it soon becomes apparent that orchards receive an excessive amount of research in relation to the value of the produce, although statistics seldom take into account the value of home-garden produce. The stimulus for research is the need for routine protection of some crops from host-specific pests (for example of pome fruit from codling moth), and in some areas of most fruit from fruit-flies, with the consequential problems of development of insecticide resistance. Again, integrated control and strictly limited use of pesticides provide the only satisfactory long term prospect. Perhaps 50% of all fruit is at hazard.

Pastures

19.5.63 Weeds and pathogens are the most serious recognised threats, although subterranean pasture-eating insects tend to be overlooked, despite the fact that their biomass may exceed several-fold the livestock above ground. Competition from rabbits is better recognised. A conservative estimate of the total pasture at hazard would be 25%. Both weeds and insects require biological control, while diseases and many insects could probably be combatted with resistant pasture varieties.

All production

19.5.64 The proportion of all kinds of primary production at hazard from pests, from disease and by competition from weeds, etc., can only be estimated. Figures collected for 1974-75 would suggest that for a gross value of \$5,400million, about one third (\$1,800million) was at hazard, that actual losses probably ran at about 1.5% (\$81million), and that the cost of the control measures taken was about another 1% (\$54million). The continued reliability of most control measures is uncertain, and in 1974-75 research to find new measures amounted to about 0.3% (\$16million). (R.A.H. Davies of ICI Australia Ltd, in a paper to Section 11 of ANZAAS 1977, independently arrived at an estimate that, of some \$3,000million worth of selected produce, about 45% was at hazard and the equivalent of 0.6% was actually spent on chemical control).

19.5.65 Table 19.10 provides a summary of the manpower devoted to protection research in different areas of work and in various organisations.

TABLE 19.10

PROTECTION RESEARCH

ESTIMATED DISTRIBUTION OF PROFESSIONAL PERSONNEL 1975(a)

	<u>CSIRO</u>	<u>Other Cwlth Government Organisations</u>	<u>State (b)</u>	<u>Univ. & CAE (c)</u>	<u>Private Sector(d)</u>	<u>Total</u>
Livestock	53	0	53	1	?	107
Cropping	83	4	231	39	?	357
Trees & Timber	18	2	15	4	?	39
Domestic Pests	1	0	2	3	?	6
Quarantine	0	6	1	0	0	7
Commercial	-	-	-	-	45	45
Basic Studies	39	1	24	30	0	94
Residues	1	1	12	0	0	14
Plant Breeding	<u>3</u>	<u>0</u>	<u>23</u>	<u>8</u>	<u>0</u>	<u>34</u>
<u>Total</u>	<u>198</u>	<u>14</u>	<u>361</u>	<u>85</u>	<u>45</u>	<u>703</u>

- (a) Figures are derived from the Commonwealth Agricultural Bureaux (CAB), 'List of Research Workers in the Agricultural Sciences', which provides a comprehensive basis for comparison in the form of staff lists annotated with nominal research interests.
- (b) Departments relating to agriculture or primary industries, forestry, lands, museums.
- (c) The CAB List omitted the Waite Agricultural Research Institute, the figures for which have been included here.
- (d) The CAB List gave no data for personnel in business enterprises. The figures here are derived from membership lists of professional societies.

SOILS, WATER AND LAND USE

19.5.66 One approach to studies of soil, water and land use is concerned with elements of the landscape rather than with individual farm performance or problems. In contrast, land management at the individual farm level seeks to maintain or increase production, and to carry this out as efficiently as possible by understanding soils, plants, animals and their interactions within a defined managerial framework. A primary consideration is the protection of soil from erosion (wind and water), salinity and declining fertility. Fertiliser, cultivation practices and rotations are obviously important. To understand soil-plant interactions it is necessary to appreciate the processes in each system. The processes

involved at the microscopic level are: transport of water within the soil, transfer of water in the soil-plant-atmosphere system, the movement of salts and fertiliser ions in terms of leaching, the partition of ions between the surfaces of soil particles and the solution within the pores, the reaction of added fertilisers, and the nature and behaviour of organic matter in soils. These processes control nutrient cycling and production, and form the basis of assessments of the supply of water and nutrients to crops.

19.5.67 Survey work is in progress throughout Australia; it ranges from broad scale land surveys to evaluate suitability of land for agricultural, pastoral and forestry purposes, to detailed surveys with scales of 1 : 50,000 or less. The requirements for surveys have changed from a national inventory of resources to requests for detailed surveys often with a specific purpose other than agriculture in mind, for example surveys at the urban fringes. Broad scale surveys of the Australian environment, using satellite imagery, are in progress after initial work in the south east of Australia (CSIRO Division of Land Use Research in collaboration with State departments of agriculture). This technique has limited use for agriculture, particularly in settled areas, but may become increasingly useful when the resolution is increased by the launching of further satellites. Most of the more detailed surveys are site-specific and are being carried out by State authorities such as departments of agriculture or of soil conservation. As field methods for assessing properties such as the water regime, salinity, hydraulic conductivity and other physical properties which are important for both agriculture and engineering, are developed, they are being incorporated into surveys because this detailed information is now required for intensive agriculture. These soil, landscape, land use and land capability surveys involve 25 staff, mainly in the CSIRO Divisions of Soils and of Land Use Research, and a further 20 in State departments. The Australian situation contrasts with overseas approaches to resource inventories where some federal authorities attempt standardisation of methods, scales and presentation of information. The various authorities within Australia use their own methods and scales in different regions. The proposed National Soil Survey Committee is only a small move towards a national approach.

19.5.68 State authorities are proceeding with tactical studies of erosion and its control by management, in association with survey work as above. The stability of landscape-soil systems in the virgin state and under various land-use situations is being determined by quantitative studies of fragile landscapes. Further strategic research of this nature is required for an understanding of the impact of clearing, tillage, irrigation and recreational activities on some of the finely-balanced landscape-soil systems such as coastal dunes, alluvial plains (e.g. irrigation in the Murray Basin) and cereal growing areas. The major problems are accelerated erosion and salinity. This work is being carried out by the CSIRO Division of Soils and by State departments of agriculture or of soil conservation. The Division of Soils is also involved in basic research on the erodibility of both soils and sediments under simulated and natural rainfall.

19.5.69 Natural landscapes and soils are in equilibrium with respect to water balances. The soil plays a major role in the hydrologic cycle by determining the proportions of rainfall which infiltrate to deeper layers or run off directly to streams or dams. These proportions are markedly affected by land use which changes the vegetation and the properties of the surface soil. Many regional surveys by State authorities now include the water regimes in the landscape-soil systems. More strategic research on water regimes throughout the year, in selected landscapes and ecosystems (for example, woodlands, eucalypt forests and orchards) is yielding valuable quantitative information which should allow the impact of current and future land use on water tables and salinity to be assessed. This work is part of the studies on fluxes within landscapes and soil profiles. Basic research at the CSIRO Division of Soils and at Flinders University on the movement of water in catchments involves the use of the isotopes tritium, oxygen-18 and carbon-14 to determine flow rates and flow patterns. Other basic work on catchment hydrology is carried out by the CSIRO Divisions of Plant Industry, Land Use Research, and Land Resources Management. It is difficult to differentiate studies on water which are directly relevant to agriculture from those done by other authorities such as departments of mines and engineering and water supply departments. Basic research on overland flow which is relevant to agriculture is conducted by the University of Melbourne, and by the State Rivers and Water Supply Commission of Victoria. In general, however, little water research is undertaken in universities.

19.5.70 Research which is fundamental to an understanding of interactions between water and the soil, particularly water entry processes and the transfer of water in the soil-plant-atmosphere system, is being carried out by the CSIRO Division of Environmental Mechanics. This Division's staff are the leading exponents of the theoretical approach to the above problems which, as well as water movement, include considerations of salt movement and fertiliser leaching within soils, and diffusion of gases. This Division has seven workers in this field of research and the Division of Soils has four.

19.5.71 With respect to water movement into the plant, two scientists at the CSIRO Division of Soils have successfully developed a model for water uptake by wheat during a growing season in relation to soil and plant parameters during the development of the crop. The CSIRO Division of Plant Industry has three workers doing similar studies, but with emphasis on the plant side of the soil-plant system. The University of New England has one scientist working on water flow at the root-soil interface. Departments of agriculture have an interest in monitoring water available to crops and in the estimation of water deficits in terms of meteorological factors (Penman equation) during the growth of the crop, and this involves about four scientists. Approximately three university workers are concerned with this topic. The CSIRO Division of Irrigation Research is primarily concerned with the growth and management of irrigated crops.

19.5.72 Salinity is a major constraint on agriculture affecting one-third of the Australian continent. Areas of natural salinity are now well documented. Strategic studies on water and salt flux in landscapes and

soils as described earlier should allow definition of land use practices which may cause salinity problems; for example, the clearing of upper slopes resulting in elevation of a saline water table on lower slopes, as in Western Australia and in the Burdekin Valley, Queensland. Various techniques have been developed for monitoring salinity in rainfall, water and soils, largely by the CSIRO Division of Soils. The major problems associated with salinity are in irrigation areas. However, research in irrigation and associated soil problems is fragmented; for example, basic work is done in the CSIRO Division of Environmental Mechanics, strategic work in the CSIRO Division of Soils, and tactical work in State departments of agriculture.

19.5.73 The screening of soils for deficiencies of plant nutrients, plus field experiments to determine fertiliser requirements for crops, is done by State departments of agriculture; some fertiliser manufacturers maintain significant R&D groups which, in addition to other research, may carry out similar work. Tests for nitrogen and phosphorus are dominant but trace elements are receiving more attention than in the past. The site-specific nature of the work necessitates a considerable work force in State departments of agriculture and of soil conservation, but this cannot be avoided as each environment, and each crop, has its own characteristics with respect to essential nutrients. Approximately 30 workers are involved. The National Soil Fertility Project, a collaborative project between the CSIRO Land Resources Laboratories and several State departments, yielded a data bank and computer techniques for predicting optimal rates of application of fertiliser. However, there appear to be no unifying concepts and site-specific trials remain a necessity. This result is disappointing as the co-operative project involved a large number of staff for up to five years. Other institutions are involved in studies of nutrient availability, especially for individual crops; for example, cotton at Narrabri, and sugar cane in northeast Queensland. (The research workers involved have been included in the section on plant production).

19.5.74 Australian soils are low in phosphorus compared with soils elsewhere in the world. In addition, supplies of phosphate are limited, and it is clear that phosphate fertilisers must be used as efficiently as possible. Large quantities of phosphate have been applied to soils over the last two decades and a significant proportion has been retained in soils in association with both inorganic and organic colloids. Further basic work on these associations is required to enable utilisation of this accumulated resource. There are about 40 workers studying various aspects of phosphate availability in soils and the use of rock phosphates. These are distributed as follows: 12 in CSIRO (Divisions of Soils, Plant Industry, and Land Resources Management), 8 in universities (principally at the University of Western Australia which has a significant program in progress on superphosphate reactions in soils) and the remainder in State departments of agriculture. This work has increased in significance because the price of superphosphate has increased three-fold since 1975. It is estimated that world rock phosphates of high grade, at present usage-rates, will be expended in 200 years. Australia is potentially well-supplied with the Duchess deposits in northern Queensland but, with increased production costs and large distances involved in transport, the

cost to the primary producer could increase sharply. A greater knowledge of nutrient cycling and better judgement of fertiliser requirements would contribute to efficiency. In this respect, the co-operative project of the WA Department of Agriculture and the CSIRO Division of Land Resources Management, called 'Project Decide', is commendable.

19.5.75 Several departments of agriculture are concerned with using 'rock phosphate' directly and are conducting research on the dissolution process and field availability (seven researchers). The CSIRO Division of Soils has two scientists concerned with 'biosuper' and two concerned with heating as a means of increasing the available phosphate content of the lower-grade Christmas Island deposits. This work also involves basic mineralogical studies by that Division's Mineralogy Section.

19.5.76 Another approach to obtaining fertiliser requirements is the study of nutrient cycling in both natural and agricultural systems. Nitrogen cycling in woodlands is being studied by the CSIRO Division of Land Use Research, and the cycling of several elements in infertile sands and in tropical rain forests by the CSIRO Division of Soils. Some work on nutrient balance in cropping situations is being carried out by departments of agriculture (three researchers). The CSIRO Division of Plant Industry also has research staff concerned with plant nutrients and nutrient cycling. Despite these efforts, basic information on mechanisms of nutrient transformations, especially the mineralisation of soil nitrogen, the effects of partial sterilisation of the soil, and the transport of nutrients from soils to plants, is deficient.

19.5.77 Transformations in soils of compounds containing plant nutrients are being studied in several universities (10 scientists), in the CSIRO Division of Soils (3), and in the CSIRO Division of Plant Industry (17). Most of the work is on nitrogen but studies on phosphorus, sulphur, manganese, iron and molybdenum are also in progress. The aim of this work is to understand the various processes within the soil which lead to accretion or release of the various nutrients, and to define conditions which lead to loss or poor utilisation of nutrients from the soil-plant system, for example, leaching and gaseous losses of nitrogen and sulphur. Such work, along with the relatively small amount of work being done on the reactions of fertilisers in soils, is fundamental to an understanding of nutrient availability and uptake. The rhizosphere, or annulus of soil close to the root which is influenced by materials lost and exuded by root systems, is an area of intense biological activity in which many reactions of importance to the uptake of nutrients and the health of the plant occur. Unavailable nutrients may become soluble; for example, phosphate can be brought into solution by the acidity produced by organisms associated with the root. Basic studies of the rhizosphere are centered in the CSIRO Division of Soils (seven scientists) and in universities. Basic work on mycorrhizae is in progress in the CSIRO Division of Soils, mainly on pines (six scientists). Inoculation of pines in areas remote from previous pine plantations, with an appropriate mycorrhiza, has yielded significant increases in growth. The fungus serves as an extension of the root system, enabling the plant to obtain nutrients, particularly phosphorus,

from large volumes of soil; this gives infected plants distinct advantages in nutrient-deficient soils. Rhizosphere studies are relatively new fields of endeavour. The information being obtained is fundamental to an understanding of nutrient uptake, and further research on plant root systems and their interactions with soils is required.

19.5.78 The cereal-legume based pasture has been so successful in southern Australia that it has received little scientific attention. The legume-grass pasture has supplied the nitrogen required by the cereal crop (although the use of inorganic nitrogenous fertilisers is increasing), and has restored soil structure, which deteriorates during the cropping phase. In the current economic climate there is a trend towards more cereal and less pasture and the transfer of nitrogen from legume to cereal becomes critical. Basic and strategic work on the fixation of nitrogen in the field, and on the biochemical processes of decomposition, of mineralisation, and of nitrogen uptake by the plant, are in progress in Perth and Adelaide, and at the CSIRO Divisions of Tropical Crops and Pastures and of Plant Industry, but more quantitative work is required for predictions of optimum management.

19.5.79 Most work on clay mineralogy is strategic; colloids control the release and retention of many nutrients essential for life. Equipment for identification of clay minerals (x-ray diffraction) and for determination of amounts of individual elements (x-ray spectroscopy) is available in most major laboratories in CSIRO, in departments of agriculture and in universities. The x-ray spectroscopic techniques were developed in the CSIRO Division of Soils. Basic studies in mineral weathering are shared between the CSIRO Division of Soils (four professional staff) and the universities (University of Western Australia with two professional staff). Basic work on the associations of heavy metals and trace elements with oxides has shown that iron and manganese oxides act as scavengers for elements such as cobalt, copper, zinc. Basic studies on minerals containing phosphate are also in progress in the CSIRO Division of Soils (eight professional staff), as is tactical research aimed at a better understanding of associations of elements in soils in natural and contaminated areas (five scientists). Examination of metal concentrations in soils and crops close to smelters in Port Pirie has shown that most of the metals, for example cadmium and lead, have been strongly sorbed in the surface layers of the calcareous soils and only a few crops had abnormal concentrations of heavy metal. Basic work on the surface chemistry of soil clays and oxides is based largely in the universities (six scientists). The mechanisms of sorption of phosphate and other inorganic anions have been defined by university groups in Perth and Adelaide. Similarly the adsorption of natural and synthetic organic materials on clays has implications for the availability of plant nutrients in soils, soil structure and the fate of herbicides, pesticides and pollutants in soils. A general theory has been developed for ion absorption which should form the basis for interpretation of plant response to added fertilisers, their residual value, soil testing and the diffusive transfer of ions from soils to plant roots.

19.5.80 Soil structure is the geometric arrangement of particles and pores. The stability of these arrangements is vital for optimum movement

of water and air into and within the soil, particularly in tilled soils. Because many Australian soils have poor physical condition, basic research on soil structure is well advanced. Quantitative descriptions of structure are possible as a result of recent work in CSIRO and universities, and factors involved in stabilising structure are being defined to the level where stabilisation is now possible, although not yet economically attractive. Basic aspects of particle arrangements and their stability are being studied in the universities (Waite Agricultural Research Institute, Universities of Queensland and Western Australia) and in CSIRO. Some recent theoretical advances in describing the structure of the tilled layer, and its change with time, will provide a basis for better co-operation between soil physicists and agricultural engineers.

19.5.81 A number of minimum tillage trials exist in Australia, largely sponsored by ICI Australia Ltd, and strategic scientific information is being obtained slowly. The CSIRO Division of Plant Industry and the State departments also have trials in progress. Surprisingly little work has been done on tillage in Australia compared with the northern hemisphere, where there are several centres dealing with the mechanics of tillage. In Australia, agricultural engineering has been strengthened by an appointment to a Chair in the University of Melbourne and by activities in several State departments, particularly in NSW and Victoria. Research at the CSIRO Division of Mechanical Engineering is noteworthy. The report of a working group to the Prime Minister on 'Rural Policy in Australia' (Canberra, 1974) at 5.146 states:

A recent Canadian investigation recommended that a substantial increase in agricultural engineering research was warranted as a high priority in that country. The arguments used would apply to Australia also. By comparison with the Australian situation in which agricultural engineering research represents possibly no more than 1% of total agricultural research expenditures, expenditures on agricultural engineering in Canadian research were equivalent to some 7% of agricultural research expenditure in 1967.

There are now about 20 professionals working in the field of agricultural engineering and 4 working on various aspects of soil structure, with basic work in the CSIRO Division of Soils and in the universities. Deficiencies in chemical fertility are now recognisable and are easily corrected. Physical deficiencies are not easily defined and amelioration is difficult. In a continent with many difficult soils, and fragile landscapes with limited water supply, R&D in this field is most important. One example of recognition of a physical problem is the definition of sodic soils and their association with poor structure and permeability, and their improvement by addition of gypsum which has proved successful in all States. Several studies on the effects of cropping regimes on structure are under way.

19.5.82 The role of fauna in soil processes is slowly becoming evident, although few scientists are studying this topic in Australia. Termites are important in nutrient cycling particularly in northern Australia, and some are involved in utilisation of pastures and other crops, while ants may be

important agents of erosion. Most of the present research work consists of surveys to obtain information on the distribution and numbers of ants, collembola and arthropods etc. in different soils. Their role in the ecosystem remains to be determined.

19.5.83 The numbers of professional research workers in the area of soils, water and land use are estimated to be distributed as follows:

CSIRO

Division of Soils	78
Division of Land Use Research	25
Division of Land Resources Management	15
Division of Plant Industry	20
Division of Environmental Mechanics	17
State Departments of Agriculture	96
Universities	25
	<u>276</u>

The figures for the CSIRO Divisions of Land Use Research, Land Resources Management, and Soils, reflect a substantial shift in policy towards environmental and urban issues, and resource assessment, over the past few years. Details of the manpower and expenditure of State and Territory departments are given in Table 19.11.

19.5.84 Another area relevant to land use, but which has not been included here, is the work on agricultural climatology. Models for agricultural production (CSIRO Division of Land Use Research) and crop adaptation (CSIRO Division of Plant Industry) depend on a consideration of soil factors in the determination of land use, and cropping frequency in relation to maintaining the nitrogen level and the stability of the soil structure. Some allowance has been made for these activities in the estimates of manpower shown above.

TABLE 19.11
SOIL CONSERVATION RESEARCH
MANPOWER AND EXPENDITURE IN STATE AND TERRITORY
DEPARTMENTS 1977

<u>State</u>	<u>Organisation</u>	<u>Professional Staff(a)</u>	<u>Estimated(a) Annual Expenditures(\$)</u>
Victoria	Soil Conservation Authority	24	500,000
New South Wales	Soil Conservation Service	45	1,600,000
Queensland	Soil Conservation Branch Department of Primary Industries	19	250,000
Western Australia	Soil Conservation Branch Department of Agriculture	6	100,000
South Australia	Soil Conservation Branch Department of Agriculture and Fisheries	7	150,000
Northern Territory	Soil Conservation Section Conservation and Agriculture Branch	5	130,000
Australian Capital Territory	Agriculture and Soil Conservation Branch	1	10,000
Tasmania	Department of Agriculture	1	10,000
TOTAL		108	2,750,000

(a) These figures relate to personnel and costs associated with soil, ecological and land use surveys which may be considered as 'investigations' rather than 'research'.

19.6 SUMMARY

19.6.1 Although there are certainly some gaps and overlaps in the current research effort in agricultural, veterinary and related biological sciences, the fact remains that the Australian achievements in this area

have been of great economic and scientific significance. Australian agricultural research enjoys an outstanding international reputation which has been due, to a significant extent, to the efforts of CSIRO in the domain of strategic and basic research. The universities have contributed to this reputation to a lesser but still substantial degree. The State departments of agriculture have made a sustained contribution in tactical research, and in this area they will continue to be the main interface with the agricultural industry. Their increased capacity in recent years in the area of strategic research has led to increased co-operation with CSIRO Divisions. It can be said that agricultural R&D in Australia is in a relatively healthy state, and continuing review of R&D activities will be necessary if this state is to be maintained; redeployment of R&D resources will also be required when new problems emerge or when serious gaps in research are identified.

APPENDIX 19.1

CROP PRODUCTION IN AUSTRALIA 1974-75

<u>AREA (thousands of hectares) 1974-75</u>			<u>GROSS VALUE (\$million)</u>		
	<u>Grain or equivalent</u>	<u>Hay, green feed, silage etc.</u>		<u>Grain or equivalent</u>	<u>Hay, green feed, silage etc.</u>
Wheat	8,308	99	Wheat	1,256	4
Barley	1,826	89	Sugar Cane	491	7
Oats	897	699	Vegetables	257	-
Sorghum	511	103	Barley	257	-
Oil-seed (Sunflower			Fruit Trees	215	-
(Peanuts			Grape Vines	102	-
(Linseed	317	-	Sorghum	76	-
(Rapeseed			Oats	60	-
(Safflower			Oilseeds (Sunflower		
Sugar Cane	253	44	(Peanuts		
Peas (mainly lupins)	144	-	(Linseed		53
Vegetables	111	20	(Rapeseed		
Fruit Trees	87	-	(Safflower		
Rice	76	-	Other Fruits	51	-
Grape Vines	71	-	Tobacco	49	-
Maize	51	7	Rice	36	-
Soybeans	46	-	Nurseries	33	-
Pastures & Grasses	100	1,033	Pastures & Grasses	13	136
Total	12,798	2,094	Total	2,896	200

APPENDIX 19.2
LIVESTOCK IN AUSTRALIA 1974-75

	Numbers (millions)	No. Slaughtered (millions)	Value of Slaughter (\$'000)	Other Products		Products Total Value \$('000)
				Quantity	Value \$('000)	
Cattle	32.8	8.297	523,387	6,496,795 (a)	520,853	1,044,240
Sheep	151.7	28.356	178,266	793,479 (b)	952,724	1,130,990
Pigs	2.2	3.447	177,741	-	-	177,741
Poultry	-	145.949	139,808	199,525 (d)	171,741	311,549
Bees	0.5 (c)	-	-	20,962 (e)	9,819	9,819
	-	-	1,019,202	-	1,655,137	2,674,339

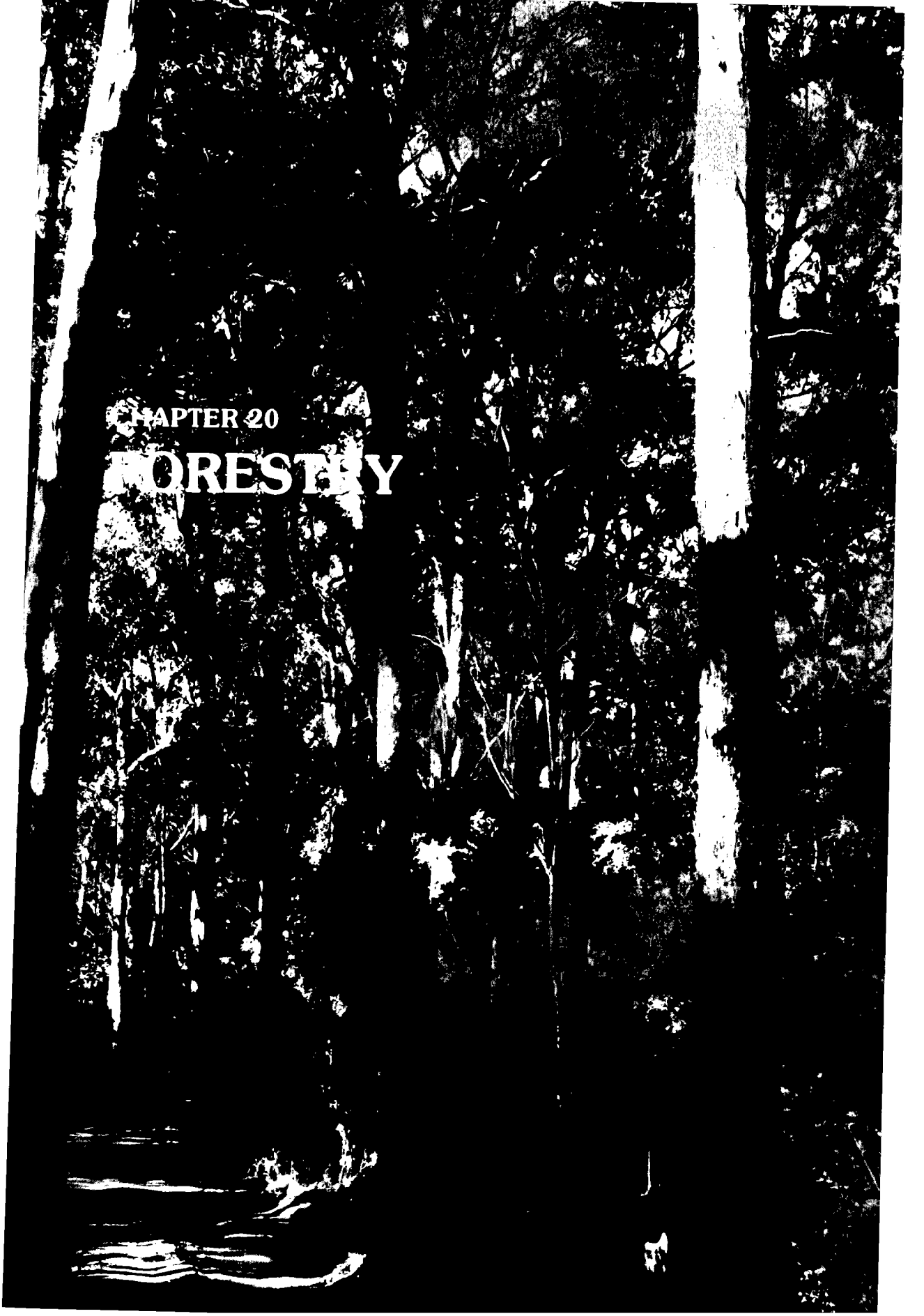
(a) Production of whole milk ('000 litres) including subsidy.

(b) Production of greasy wool ('000 kg).

(c) Total number of beehives.

(d) Egg production ('000 doz.)

(e) Production of honey and beeswax ('000 kg).



CHAPTER 20

FORESTRY

Photograph: Mixed native forest of Eucalyptus bosistroana, E longifolia and E. muellerana on the south coast of NSW. Forestry R&D is concerned with the long-term management of forests for the production of timber and other raw materials, for the supply of water from forested catchments, for recreation, and for conservation of flora and fauna.
(Photograph courtesy CSIRO Division of Forest Research).

CHAPTER 20

FORESTRY

20.1 INTRODUCTION

HISTORY OF FORESTRY IN AUSTRALIA

20.1.1 Most of the State forest services were formed in the early 1900s. One of their major roles at that time was to seek the formal dedication and reservation of forested land, much of which was being cleared for agricultural purposes, often with little regard to its long-term suitability for such use. The control of forest harvesting operations and the discouragement of illegal operations were other major functions, together with the control of fires.

20.1.2 The survey, mapping, classification and dedication of Australia's forests, along with the gradual improvement in control and management of commercial operations, received the major emphasis in the management of native forests up until the late 1950s and early 1960s. Intensive research into native forest management and protection, particularly the regeneration of the major eucalypt forest types, began in the 1950s.

20.1.3 In addition to the early efforts to conserve the native forests, which were mainly hardwoods, and to dedicate sufficient forest areas to meet the States' needs, the forest services carried out extensive testing and research to find the best softwood species to grow and the best ways of establishing softwood plantations. Except in South Australia where the establishment of softwood plantations commenced in the late 19th century, the major effort to test and prove species did not begin until the 1920s. With the increase in softwood planting after the second World War, R&D into the silviculture and management of the major softwood species was intensified, and is now maintained at a high level for the species being planted.

20.1.4 Research into the regeneration of the major native forest types showed that clear-felling was necessary in many areas if productive stands were to be established. The development of the export woodchip industry in the late 1960s provided a means of effectively regenerating large areas of forest from which the best trees had been removed in the past or had been damaged by fire.

20.1.5 The enactment of the Softwood Forestry Agreements Act of 1967 and the subsequent Acts of 1972 and 1976, which have as their underlying aim the achievement of national self sufficiency, resulted in an increase in the annual softwood planting program which previously the States

themselves and industry had financed in the main. The Acts enabled the purchase by State forest services of significant areas of farmland for planting, but in general the land purchased had been imperfectly cleared or was inadequately regenerated with commercial tree species. For the most part, however, the plantations were established on State forest or Crown land with native forest cover of little commercial use.

20.1.6 Because of society's increasing awareness of the need for environmental protection and concern for quality of life, the early 1970s saw the commencement of the present conflict between sectors of the environmental movement and the forestry profession over the management of native forests.

FORESTS IN AUSTRALIA

20.1.7 Australia has 43.0 million hectares of forest potentially available for harvesting (Table 20.1). Of this, 12.4 million hectares of publicly-owned land are permanently dedicated for timber production; another 19.6 million hectares are not permanently reserved for timber production, but the Crown has control over any harvesting operations. A further 9.0 million hectares are owned by individuals and companies and much of this is expected to be available for commercial harvesting. About 98% of the forest area is native forest, 35 million hectares being dominated by eucalypts, the remainder being rainforest or cypress pine. The area of softwood plantations totalled almost 700,000 hectares at 31 March 1978.

TABLE 20.1
FOREST AREAS OF AUSTRALIA - 1977
(all figures in thousands of hectares)

	Native Forest[a]	Plantation	Total area[a]
State and Territory forests	11,900	484	12,400
Other publicly-owned forest	19,600	5	19,600
Forest owned by companies or individuals	8,900	170	9,000
National Park	2,000	1	2,000
Total	42,400	660	43,000

[a] Figures in these columns have been rounded to the nearest hundred thousand hectares.

Source: Australian Forest Resources 1977; Commonwealth Department of Primary Industry.

20.1.8 The definition of forest used in the above data is based on criteria relating to its suitability for commercial wood production. Using the United Nations Food and Agriculture Organisation (FAO) definition, the area of forest in Australia is close to 100 million hectares. Major uses of the additional 60 million hectares of forest include water supply, recreation, and wildlife and soil conservation. It is emphasised, however, that forests managed for wood production may also yield these non-wood objectives, and in parts of these forests the maintenance of non-wood values could become the primary aim of management.

20.1.9 About 80% of all forest land in Australia is publicly-owned and controlled by the relevant State or Territory government. The private forestry sector comprises a small group of companies (including the pulp and paper companies), which produce wood commercially, and a much larger group of farmers for whom wood is largely produced on uncleared farm land. Total employment in forestry in 1976-77 was just over 19,000.

20.1.10 Yields from native forests used for wood production are very low (0.1 to 5 cubic metres per hectare per annum) compared with yields obtainable from plantation pine or plantation eucalypt forests (10 to 25 cubic metres per hectare per annum). In addition, the supply of softwoods from indigenous forests is inadequate, and substantial areas of exotic softwoods have been established by both State authorities and industry. Australia is at present a net importer of forest products, but as the area of pine plantations increases, forest products imports should decline.

20.1.11 The overall production from native forests, using present utilisation practices, is about 1 cubic metre per hectare per annum, while that from plantations is about 18 cubic metres. This contrast results from differences in the proportion of the available wood which is harvested, in the growth potentials of the tree species used, and, principally, in the intensity of cultivation. Given the availability of finance and access to markets for pulp wood, yields from much of the native eucalypt forest could be increased substantially through improvements in any of these factors, although, in many areas, it is not certain if high yields could be sustained over several rotations without the use of fertilisers and pest control measures. Where markets are available, increasing the yields of the native forests or planting exotic softwoods would in general be economic and would put to good use forest areas that are now largely non-productive of wood. Forest areas which are close to markets, and which have the required site quality and adequate rainfall, obviously have the best potential for a large improvement in yield. Assessments should be undertaken to determine accurately which forest areas might be suitable for improvement, and what costs would be involved.

VALUE OF FOREST PRODUCTION

20.1.12 For the chief industries that use the direct output of forests, the value of raw materials at the mill door was \$233million in 1976-77 (provisional figure). The \$233million includes value added in transport from roadside loading to mill door. Although data are not available to

substantiate the statement, it is believed that on a national basis most of the wood came from the 12.4 million hectares of permanently-dedicated Crown forests, and from company forests and pine plantations.

20.1.13 It is difficult to place a reliable value on the non-wood output from any forest area. As there are 100 million hectares of forest according to the FAO definition, the aggregate value of non-wood production would be significant. In metropolitan catchments, the value of water production may exceed that of wood production, if indeed the latter is permitted at all. Having regard to projected estimates of demand at the time, the FORWOOD Panel Report No. 3 (published by the Australian Government Publishing Service, 1974) recommended that in areas of multiple use the highest priority in the management of these forests be given to water production.

STRUCTURE OF THE FOREST INDUSTRY

20.1.14 In contrast to the situation in most developed countries, private forestry plays a relatively minor role in Australia, contributing only about 20% of production. A few major industrial companies have established softwood plantations to ensure their future supplies of raw material. In Tasmania, a significant proportion of the State's pulpwood is obtained from privately-owned land.

20.1.15 The State and Commonwealth forest services have responsibility for controlling the harvesting operations on all publicly-owned land. With few exceptions, wood is sold standing in the forest, the forest products industry being responsible for the felling and transport of the log to the mill. The forest products industry in turn has generally sub-contracted this harvesting operation to small operators. These circumstances have led to a low investment in R&D in harvesting generally, and particularly by State forest services, considering its significance in the cost of wood delivered at the mill; approximately three-quarters of the value of wood at the mill door, equivalent to \$175million, is attributable to harvesting. As the methods of harvesting timber are largely common to any area in Australia, the Commonwealth would seem better placed to conduct harvesting research than the State forest services; the participation of the forest products industry, particularly the major forestry companies which have the interest, resources and scale of operations to improve the economics of harvesting, is essential.

20.2 ORGANISATION, AGREEMENTS AND FUNDING

ORGANISATION

20.2.1 Forestry R&D is defined for the purpose of this paper as being concerned with all aspects of the growing, management, protection and harvesting of wood, the economics of wood production, and with the general forest environment. Forestry operations are normally considered to cover all operations until the log reaches the mill door, although for the reasons given in paragraph 20.1.15, insufficient research is conducted on harvesting. Research into wood properties (Chapter 32) has not been included, although obviously this is related to forest management.

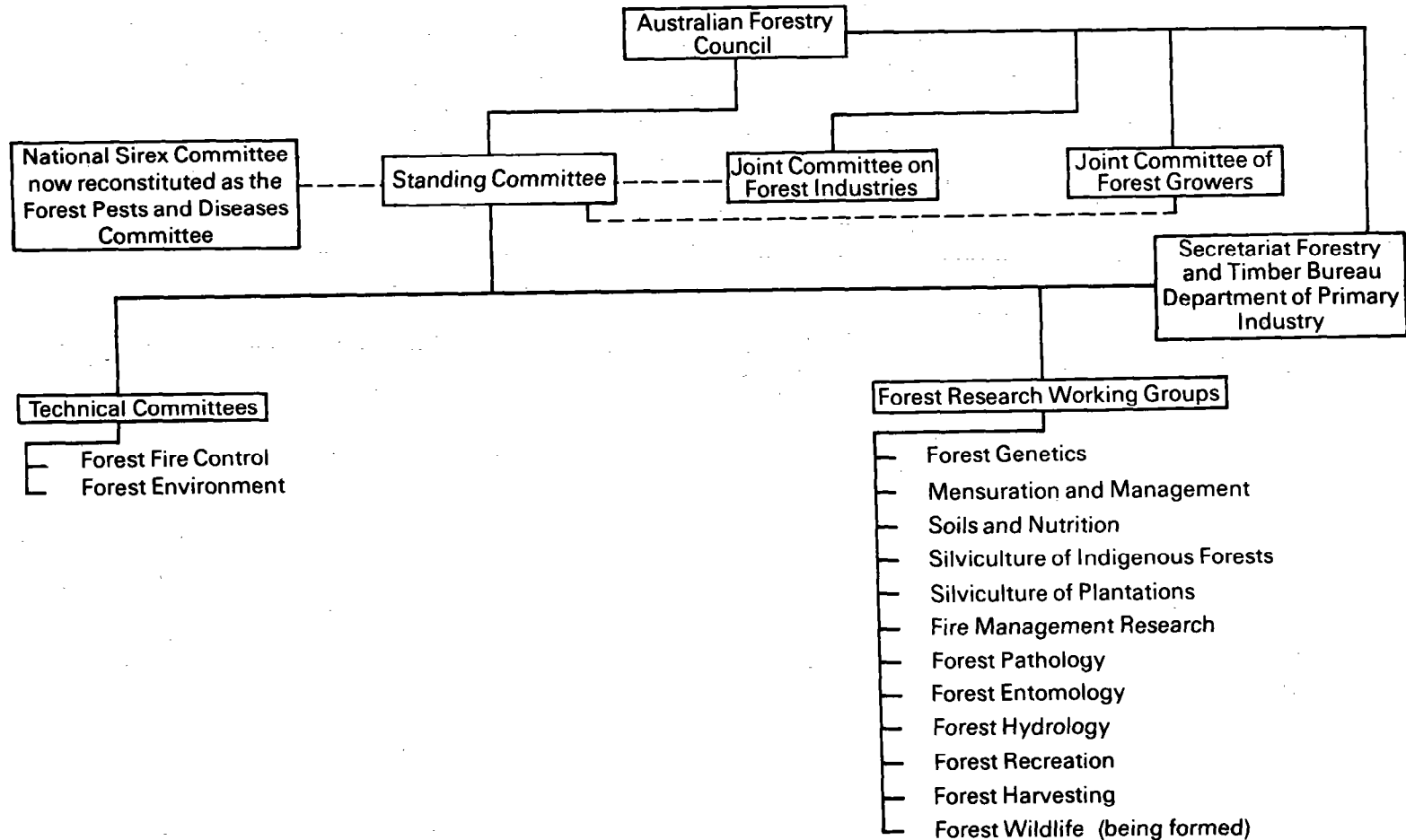
20.2.2 R&D in forestry in Australia is conducted by over 35 organisations, about 20 of which have a major interest. A very large proportion of the research, however, is conducted by the State forest services and the CSIRO Division of Forest Research. Two tertiary educational institutions, the Australian National University and the University of Melbourne, and two major, industrial, forest products companies, support smaller but significant programs. The remaining organisations, principally tertiary educational institutions and other divisions of CSIRO, have a varying interest and involvement in forestry but no commitment to maintain forestry R&D programs. Nevertheless, the contributions of such organisations to the knowledge of forestry is important because they are able to investigate special problems.

20.2.3 It is recognised that individual organisations, by virtue of their structure and activity, are particularly suited to certain forms of research. Thus, in general, the State forest services conduct mainly applied research and the Commonwealth mainly basic research. In some cases, however, there is a joint research effort.

20.2.4 Valuable co-ordination of research in Australian forestry is achieved through the activity of the Australian Forestry Council's Research Working Groups (RWGs). Each RWG meets about every two years to review activity, to discuss needs for future R&D and to formulate recommendations to the Standing Committee of the Council. Their objectives are to co-ordinate research and to identify research needs. Individual organisations determine their own R&D programs and priorities according to their needs, and take into account the reports to, and the agreements reached by, the Standing Committee. The organisational structure of the Australian Forestry Council is shown in Figure 20.1, and a list of the organisations represented on the Research Working Groups is published annually in 'Australian Forest Resources' by the Forestry Branch, Commonwealth Department of Primary Industry.

20.2.5 The Australian Forestry Council has sponsored conferences and symposia at which research problems and priorities have been discussed, the best-known being the FORWOOD Conference, one Panel of which was concerned with education, research and training. Other examples include the sponsoring of major symposia on forest tree nutrition and 'dieback' in eucalypts. Further symposia are planned.

FIGURE 20.1
ORGANISATION OF THE AUSTRALIAN FORESTRY COUNCIL AND ITS
COMMITTEES AND WORKING GROUPS



20.2.6 A Forest Research Advisory Committee has been established to advise the CSIRO Executive on the overall research priorities of the CSIRO Division of Forest Research. Its membership includes representatives of the Standing Committee of the Australian Forestry Council and two of its sub-committees, forest industries, an industry association and a university forestry school; and an ecologist concerned with non-wood forest uses. Smaller committees advise the Chief of the Division in respect of the research programs of the regional stations which the Division operates in the States.

AGREEMENTS

20.2.7 There are no comprehensive national or international agreements concerning forestry R&D. However, bilateral, co-operative arrangements exist between organisations involved in research, and there are both formal and informal arrangements between companies and corporations in the forest industry within Australia and internationally. About a dozen separate organisations conducting forestry R&D in Australia are members of the International Union of Forest Research Organisations (IUFRO), the major function of which is the co-ordination of research and the dissemination of research results. Membership does not imply, however, that an organisation is committed in any way, or has any formal obligations.

20.2.8 One multilateral co-operative arrangement existed under the aegis of the National Sirex Committee. The State forest services, major forest-owning industrial companies, CSIRO, and Commonwealth departments contributed in varying ways to a joint program which resulted in a substantial degree of control of the Sirex wood wasp. The committee was recently reconstituted as the Forests Pests and Diseases Sub-committee of the Australian Forestry Council, which will consider all pests and diseases of major concern to forestry.

FUNDING

20.2.9 Organisations undertaking forestry R&D are funded by their controlling authority, that is, Commonwealth or State government, or industrial companies. Additional funds may be made available to universities, CSIRO, or industry associations by industry and the State forest services, in support of specific projects. Grants are also made by the Australian Research Grants Committee and the Rural Credits Development Fund. Forestry is unlike other primary industries in that there are no specific industry levies, either Commonwealth or State, with the express purpose of supporting research projects. State forest services' research is financed, along with other expenditure, out of loan funds, consolidated revenue, and stumpage charges. This is because the governments are the major crop growers in the forestry industry.

20.2.10 The State forest services, which have the primary responsibility of maintaining raw material supplies to forest industries, generally have the added responsibility of preserving the non-wood values of forests. Revenues obtained from the forest are derived, however, almost wholly from royalties on wood removed. Recreational facilities and maintenance of water quality, for example, are not paid for directly by those who benefit.

20.2.11 Much of the current research in forestry, especially that related to the establishment of softwood plantations, represents an investment for the future. Production of wood from Australian forests will almost double when plantations now being established mature. The future investment aspect, coupled with the high but non-quantifiable non-wood values of forests, makes it very difficult to establish a yardstick against which the adequacy of funding for R&D may be judged.

20.2.12 The Commonwealth Department of Primary Industry awards postgraduate scholarships in forestry, up to the equivalent of six scholarship-years annually, tenable at Australian universities. Most recipients conduct research into specialised aspects of the effect of forestry operations on the environment. Some of the paper-manufacturing companies from time to time provide postgraduate scholarships in forestry. Those wishing to do postgraduate research in forestry at tertiary institutions are able to apply for other scholarships of a more general nature.

20.3 DESCRIPTION OF R&D ESTABLISHMENTS

COMMONWEALTH GOVERNMENT

20.3.1 CSIRO Division of Forest Research (DFR). The Division of Forest Research was formed on 1 July 1975 by the transfer of the functions, staff and assets of the Forest Research Institute and other research groups formerly within the Forestry and Timber Bureau. The Division is based in Canberra and maintains regional stations in Queensland, Victoria, Tasmania, South Australia, Western Australia and the Northern Territory. The Division has positions for 232 staff. Major long-term projects within the fields of assessment, development, protection and harvesting are maintained. The Division is represented on the Standing Committee of the Australian Forestry Council and has a substantial involvement in the activities of a number of the Council's Research Working Groups.

20.3.2 Total expenditure for 1976-77, including some overheads, was \$4.34million. The Division conducts research in five of the six areas described in section 20.4. Expenditures (1976-77) in these areas were; silviculture 45%, management of environment 20%, protection 17%, harvesting 10%, management 8%. No research into the economics of forestry

was conducted during the period. Funds were distributed to eucalypt research 49%, softwoods research 42% and rainforest research 9%.

20.3.3 CSIRO Division of Entomology. The Division is based in Canberra. During 1976-77 \$222,000 was expended on research directly related to forestry, involving 13.5 man-years of effort. Areas investigated were, biological control of the *Sirex* wood wasp, management of insect pests in eucalypt plantations, prevention of termite attack, and ecology of the jarrah leaf-miner.

20.3.4 CSIRO Division of Soils. The Division is based in Adelaide, close to the Waite Agricultural Research Institute. During 1976-77 forestry projects, involving 10.5 man-years, were funded by Treasury (\$158,000) and industry (\$17,000). Projects involve investigations of soil and nutrition interactions in both the pre-establishment and the post-establishment phases of forest plantations. The objectives are to optimise productivity of the soil-tree system with special emphasis on Pinus radiata in both first and second rotations.

20.3.5 CSIRO Division of Land Resources Management. The Division is based in Perth. During 1976-77 \$790,000 was expended on forestry research, involving 40 man-years of effort. Research emphasis was on management of the environment, with minor projects concerned with farm wood lot management and forest pathology.

20.3.6 CSIRO Division of Land Use Research. The Division is based in Canberra. During 1976-77 \$423,000 was spent on research related to forestry, which involved 24 man-years. Major effort was conducted under the heading of management of environment and was concerned with woodland ecology, involving investigations of management for different uses. Other effort under the heading of management involved evaluating land resources in general terms of forest production.

20.3.7 CSIRO Division of Plant Industry. The Division is based in Canberra. During 1976-77 \$296,000 was spent on research directly related to forestry involving 24 man-years. Major forestry research concerned management of the environment, and involved studies of multiple-use of forests and ecological surveys.

20.3.8 Bureau of Agricultural Economics(BAE). The Bureau, which is part of the Commonwealth Department of Primary Industry, became involved in forestry economic research, with particular emphasis on marketing, following a recommendation by the House of Representatives Standing Committee on Environment and Conservation that the BAE examine the economics of the softwood industry. A report on this topic was published in December 1976 following a study involving about three man-years of effort. The Bureau has now established a forestry commodity economic research section.

STATE FOREST SERVICES

20.3.9 Forestry Commission of NSW. Research is conducted by the Wood Technology and Forest Research Division based in Sydney and by its country research centres at Coffs Harbour, Taree, Bathurst, Tumut and Eden. During 1976-77 total expenditure on forestry research was \$1.16million, involving 64.5 man-years of effort. Proportional expenditure on the major areas of research was; silviculture 34%, management of the environment 29%, protection 22%, harvesting 6%, economics 6% and management 3%. Forty-five percent of effort was on softwoods, 50% on native forests and 5% on rainforests. Environmental research was directed towards investigating the impact of forestry operations on water resources, wildlife, flora and soils. During 1976-77, increased emphasis was placed on harvesting research and protection research, particularly on tree diseases such as Phytophthora and Dothistroma. There was a corresponding decrease in activity in the traditional forestry research areas of inventory, growth studies, weed control, species trials, nursery management and forest regeneration systems.

20.3.10 Forests Commission of Victoria. Research facilities are in Melbourne and Creswick. During 1977 \$1.24million was spent on forestry research, involving 68 man-years of effort. Proportional expenditure was; silviculture 35%, management of environment 27%, protection 20%, management 11%, economics 4% and harvesting 3%. The major research effort sought to provide the scientific basis for the increasingly complex requirements of forest management. Emphasis was given to integrated studies of the impact of silvicultural practices on forest ecosystems. Studies of nutrient distribution in mixed eucalypt forests were conducted to provide information on the likely long-term effects of alternative regimes of management. Research into the effects of management on the presence and density of species of plants, insects and mammals in stands of various ages was continued, and specific studies of aspects of the ecology of pine plantations and eucalypt forests were completed.

20.3.11 Department of Forestry, Queensland. Forestry research is conducted at five regional research stations. Atherton Regional Research Station concentrates on the silvicultural treatment of the rainforests of north Queensland. In addition it conducts research into plantations of hoop pine and caribbean pine on the Atherton Tableland and the tropical lowlands in the vicinity of Cardwell. Beerwah Regional Research Station concentrates on silviculture, tree breeding, and nutrition research relevant to the establishment and maintenance of exotic pine plantations on the coastal lowlands south of latitude 23 degrees. Dalby Regional Research Station carries out research in the white cypress pine, ironbark and spotted gum forests in the area west of Dalby and Warwick with an annual rainfall of 500-700 mm, and in rainforests and sclerophyll forests on the Dividing Range east of Warwick where the rainfall generally exceeds 1,200 mm per annum. Research is also carried out on the growth of trees suitable for planting as wind-breaks and shelter-belts on the agricultural and pastoral land west of the Dividing Range. Gympie Research Station concentrates on increasing the productivity of wet and dry sclerophyll forests in coastal south Queensland. It also investigates re-vegetation of

sand-mined areas and the multiple use of timber and pasture in spotted gum-ironbark forests. Imbil and Yarraman Research Stations are mainly concerned with research into the establishment and maintenance of plantations of hoop pine on rain forest sites in south Queensland. During 1976-77 \$1.43million was spent on forestry research which involved 100 man years of effort. Proportional expenditure was silviculture 84%, protection 10%, management of environment 4%, management 1% and harvesting 1%. Funds were distributed to softwood research 75%, rainforests research 13% and native forest research 12%.

20.3.12 Woods and Forests Department of South Australia. The Department conducts most of its research as in-field projects. Laboratory work is done in collaboration with other organisations, such as CSIRO and the universities. During 1977, \$685,000 was spent on forestry research, involving 32 man-years of effort. Proportional expenditure was; silviculture 42%, management 42%, protection 8%, harvesting 5% and management of environment 3%. The bulk of the silvicultural work undertaken is directed towards maintaining or increasing the productivity per unit area of land and, as such, includes considerable research on means of offsetting the productivity decline noted in second rotation plantations.

20.3.13 Forests Department of Western Australia. Research is conducted from Perth and from the Dwellingup Research Station. During 1976-77 \$1.56million was spent on forestry research, involving 90 man-years of effort. Proportional expenditure was; management of environment 40%, management 20%, silviculture 18%, protection 16%, harvesting 4% and economics 2%. The major research effort into management of the environment involved assessment of resources. A major study of vegetation and other characteristics at selected sites in the northern jarrah region was completed and is being used as the basis the planning of land use, and the establishment of priority areas for special management in the conservation of fauna and flora. A major study concerned the assessment of forested catchment in terms of the quantity and quality of water yielded. Other projects involved studies of the effect of individual forest operations, multiple use management, aesthetics and landscape design, and urban forestry.

20.3.14 Forestry Commission of Tasmania. The Commission's research facilities are based in Hobart. During 1976-77 \$545,000 was spent on forestry research, which involved 35 man-years of effort. Proportional expenditure was; management 40%, silviculture 32%, protection 19%, management of environment 7% and economics 2%. The major effort in management research was devoted to projects for the control of resources and yield; estimation of defect in rainforest species, development of area and volume inventory systems, estimation of logging residue, growth of native forest species, and evaluation of alternative management regimes. Forty nine percent of silvicultural research effort was on Pinus radiata plantations, 34% on eucalypt forests, and 17% on rainforests.

OTHERS

20.3.15 Forestry companies. Several companies conduct research but only two major companies have large research programs. APM Forests Pty Ltd is the forests subsidiary of Australian Paper Manufacturers Ltd, and during 1976-77 it spent \$211,000 on forestry research. This involved 10 man-years of effort, particularly in the field of silviculture but with minor projects in management and harvesting. Improvements have been made in the rate of growth of trees, and the costs of wood production have been reduced. In addition, the company supported 18 individual projects by various Australian institutions, particularly universities, to the value of \$52,000. Associated Pulp and Paper Mills Ltd spent \$171,000 on forestry research in 1976-77 with particular emphasis on silviculture and management; protection and management of the environment also gained substantial support.

20.3.16 Australian National University. The Department of Forestry maintains a wide-ranging research program, with emphasis on providing the scientific basis for subsequent research conducted by other institutions. During 1977, \$462,000 was spent on forestry research, involving 40.7 man-years of effort (this included 28 man-years of research student effort). The area receiving most attention was silviculture.

20.3.17 Other universities. At the University of Melbourne the Faculty of Agriculture and Forestry maintains a research program with emphasis on managing the environment, and during 1976 \$94,000 was spent on forestry research, involving 5.6 man-years of effort. At the University of Queensland the Departments of Agriculture, Botany and Zoology expended an estimated \$54,000 on forestry research during 1976, involving 11 man-years of effort. The Department of Botany at Monash University is investigating the penetration and establishment of Phytophthora cinnamomi into disease-tolerant and susceptible eucalypts; the annual expenditure of \$5,000 involves one man-year of effort. The Department of Earth Science of Flinders University is investigating the influence of pine plantations upon water resources with a view to determining the role of land use in water conservation; the annual expenditure of \$3,000 was associated with 0.5 man-years of effort. At La Trobe University the Schools of Agriculture and Biological Sciences maintain small programs of forestry research, which involve the expenditure of \$53,000 and 5 man-years of effort.

20.3.18 A summary of the manpower and expenditure devoted to forestry R&D in Australia in 1976-77 is given in Table 20.2

TABLE 20.2

SUMMARY OF MANPOWER AND EXPENDITURE IN FORESTRY R&D 1976-77

	<u>Staff</u> (equivalent man-years)		<u>Expenditure</u>
	<u>Professional</u>	<u>Non-Professional</u>	\$'000
COMMONWEALTH INSTITUTIONS			
Silviculture	30.0	97.5	2,141
Management	5.4	9.8	282
Harvesting	5.8	16.2	437
Environment	50.4	79.3	2,408
Protection	17.1	41.8	984
Economics	3.0	-	34
TOTAL	111.7	244.6	6,286
STATE FOREST SERVICES			
Silviculture	68.5	120.0	2,772
Management	21.0	46.0	1,015
Harvesting	5.0	4.0	209
Environment	33.5	30.5	1,405
Protection	32.5	22.5	1,044
Economics	5.0	3.0	172
TOTAL	165.5	226.0	6,617
OTHER RESEARCH ESTABLISHMENTS			
Silviculture	5.0	24.5	442
Management	3.6	8.4	177
Harvesting	1.6	3.5	77
Environment	6.9	12.6	170
Protection	1.9	11.9	184
Economics	0.8	0.5	14
TOTAL	19.8	61.4	1,064
GRAND TOTAL	297.0	532.0	13,967

SILVICULTURE

20.4.1 Silvicultural R&D is concerned with the growing and tending of trees. It includes examinations of the factors essential for tree growth, for example soils and nutrition, methods of site preparation, nursery practice, tree improvement, planting, weeding, fertilising and pruning, and is the area in which most research is conducted. Research is largely restricted to the State forest services, the CSIRO Division of Forest Research and the Australian National University Department of Forestry. Useful results from silvicultural research are being obtained also by APM Forests Pty Ltd.

20.4.2 Expenditure on silvicultural research in Queensland is particularly high at 85% of total expenditure; this effort is mainly on softwoods. The Western Australian Forests Department spent only 18% of research funds on silviculture. This is perhaps a reflection of the fact that, in contrast to other States, there are only three eucalypt species in Western Australia of major commercial importance. It may also be an indication that funds are being diverted from silvicultural research to research into environmental problems. Because of their relatively small area, the Western Australian forests are under greater pressure for recreational use, water conservation and wildlife protection than is the case in other States.

MANAGEMENT

20.4.3 The term management as used in this report refers to forest management for wood production. It encompasses such areas as the development of forest assessment techniques, and techniques to determine the desirable rate of cutting to meet various objectives. As would be expected, the organisations with significant R&D efforts are the State forest services and the CSIRO Division of Forest Research (CSIRO DFR). Industry and the two universities teaching forestry have some input. CSIRO DFR is concerned mainly with basic and strategic research, and with the application of remote sensing techniques to forest assessment: the State forest services are involved in applied research to a greater degree.

20.4.4 The proportion of research effort in production management varies considerably among States. The large expenditures by South Australia and Tasmania can be explained in terms of the stage of development in those States of capital intensive industries which require continuity and predictability of supply. The reasons why New South Wales and Queensland are doing very little research of this type are not readily apparent, but may reflect an increased emphasis on environmental, protection, and harvesting research at the expense of the more traditional research areas.

HARVESTING

20.4.5 Harvesting is often thought of as commencing at the stump and finishing at the roadside landing or possibly on the truck; but harvesting should be integrated from the stump to the breaking-down saw or from the stump to the chipper. Moreover, the grower should be concerned with harvesting, because attributes of the plantation such as the spacing, form and size of trees, as well as intrinsic properties of the wood, will affect harvesting, transport and end use. Ideally the whole operation should be integrated from planting to end use. The aims of harvesting R&D are to reduce costs, to improve safety, and to minimise environmental damage.

20.4.6 Because forest services sell at the stump, they have tended to ignore harvesting R&D, leaving it almost entirely to CSIRO DFR and the wood-using industries. The Commonwealth still has the major input through DFR and, more recently, through the CSIRO Division of Mechanical Engineering. The major companies in the forest products industries also place importance on harvesting R&D, and some are obtaining useful improvements in harvesting methods.

20.4.7 The cost of harvesting represents a significant proportion of the costs of sawn timber or chips. It is generally recognised at both Commonwealth and State level that harvesting R&D has not been afforded sufficient priority in the past. Apart from the gains in efficiency which might be expected, there is considerable room for improvement in the industry's safety record. At the present time, expenditure on harvesting R&D by some State forest services is minimal, and that by others non-existent.

ENVIRONMENT

20.4.8 Research on management of the environment, or management for non-wood forest values, includes studies of the effects of particular forest operations on the environment, aesthetics and landscape design, ecological and recreational surveys, and identification of forest areas with historical or other special values. Because of the broad scope of this area of research, almost all organisations which responded reported research projects. Some CSIRO Divisions which responded to our questionnaire reported expenditure on environmental research of around \$500,000. On closer examination of the projects involved, it was considered that the results of this research would have little bearing on the management of forests for wood production, but would relate to management for non-wood uses. Victoria, New South Wales and Western Australia had substantial expenditure on environmental research.

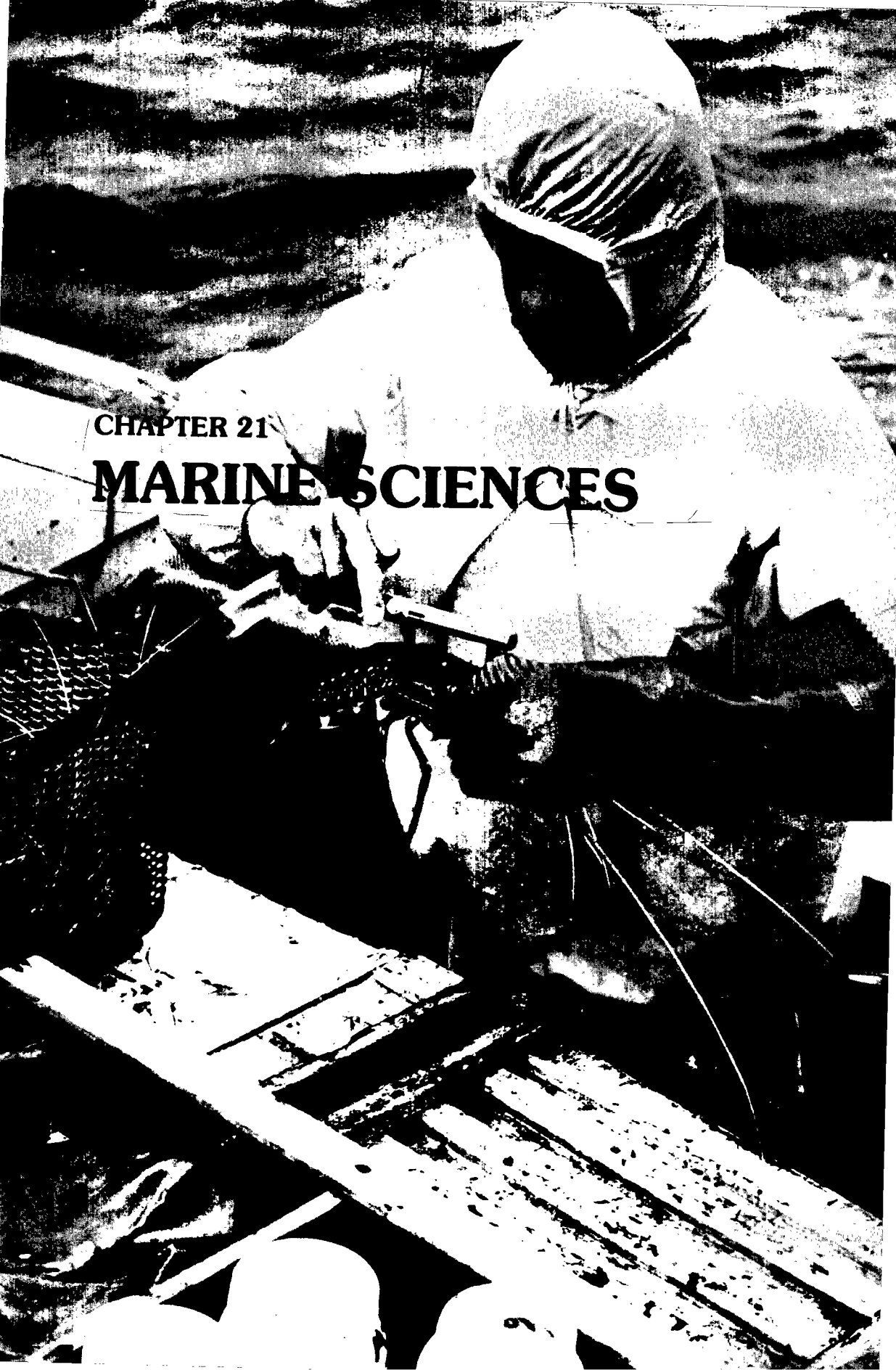
PROTECTION

20.4.9 Protection R&D includes the major fields of forest pathology, entomology and fire behaviour. In addition to the State forest services

and CSIRO DFR, other Divisions of CSIRO (particularly the Divisions of Entomology, Soils, and Plant Industry) have a substantial involvement. Expenditure by the State forest services on protection research was approximately 20% of total research expenditure with the exception of South Australia and Queensland, where the proportion was much lower. The Forests Commission of Victoria pointed to the need for further protection research. The problem of Phytophthora cinnamomi has received a lot of publicity, and more work oriented toward control through forestry practices is needed.

ECONOMICS

20.4.10 Current projects in forestry economics include studies of the supply and demand for forest products as a basis for determining the area of forest required for wood production. They also include studies which aim at the improvement of efficiency in forest operations and studies of the costing and accounting methods applied to forestry projects. Economics has received a low priority in the past, but the staffing of positions at the Bureau of Agricultural Economics should improve the situation. The forest services are sometimes criticised because they do not subject forestry development projects to close scrutiny on economic grounds before committing large areas of forest to development. Economic research on forestry in Australia needs to be expanded by the assembly of appropriate data, and by more effort by both State and Commonwealth authorities.



CHAPTER 21

MARINE SCIENCES

Photograph: A Western Australian Fisheries and Wildlife research officer measures rock lobsters near the Abrolhos Islands. The western rock lobster fishery, currently worth more than \$40million annually, is one of the most efficiently managed fisheries in the world, and is the subject of a comprehensive R&D program which includes the monitoring of catch size and the assessment of stock numbers.

(Photograph courtesy Commonwealth Department of Primary Industry).

CHAPTER 21

MARINE SCIENCES

21.1 AN OVERVIEW

DEFINITION OF AREA COVERED

21.1.1 The marine sciences comprise all those scientific R&D activities that are concerned with the marine environment. This environment extends from estuaries and coastal dune systems to the open ocean and its seabed. The marine sciences are concerned with the knowledge and understanding of this environment and its influence on the land, particularly along the coastal margin. They cover a very wide range of subjects and activities ranging from studies of the taxonomy of the smallest living marine organisms to studies of the age and structure of the seabed, and from observations of the interactions of a community of organisms in a tidal swamp or estuary to theoretical modelling of the water movements of a whole ocean. The chemistry of sea water and the dispersion and effects of natural and introduced substances are also matters of interest.

21.1.2 The marine sciences can be seen in terms of either the scientific disciplines that are involved or the objectives (or applications) to which the R&D activities are, or could be, directed. Other considerations, such as whether the R&D is performed inshore or in the open-ocean, can also be useful foci for discussion. The following set of disciplines and objectives has been adopted as the main framework for this chapter:

- . marine biology (including fisheries);
- . marine geosciences (including off-shore exploration);
- . oceanography; and
- . environmental studies.

Although these distinctions have been made to assist discussion, it must be emphasised that there are no rigid boundaries in the marine sciences and that other valid groupings are possible. That these distinctions have been drawn is not to suggest that they should necessarily form the basis for the funding or conduct of the marine sciences.

POLICIES AND AGREEMENTS

21.1.3 As with many other matters in Australia, the marine environment is an area in which both the Commonwealth Government and the State Governments have rights and responsibilities. However, although

government policies have been developed to cover such matters as maritime defence, fisheries and off-shore exploration, Australians and their governments have, in the past, been relatively preoccupied with their activities on the land, and the marine environment has not attracted much attention. Recently, two events have resulted in an increased interest by the Commonwealth Government in this area:

- clarification of the Commonwealth Government's sovereignty over the territorial seas as a result of the High Court decision on the Seas and Submerged Lands Act; and

- developments at the United Nations Conference on Law of the Sea, concerning coastal state rights out to 200 nautical miles.

21.1.4 Following the passage of the Australian Institute of Marine Science Act 1970, an Interim Council of the Australian Institute of Marine Science was established to plan the Institute which is located at Townsville in Queensland. In making its Report in 1971-72[1] the Interim Council attempted to assess the problems and needs of the marine sciences in Australia and to provide a background for its specific recommendations. The Report covered such matters as the current situation, the Townsville Institute, other research needs, an Australian Marine Science Council and the role of universities in the marine sciences. This Report is a valuable reference document and most of its observations are as relevant today as in 1971-72. However, though the Interim Council's Report canvassed wider issues than just the establishment of the Institute, there remained a need for a more broadly-based and quantitative review of the marine sciences. With the passage of time a more up-to-date assessment has also become a pressing need.

21.1.5 During the period 1972-75 many proposals for initiatives in the marine sciences were received by the Government, mainly from the universities. The then Minister for Science and Consumer Affairs (the Hon. Clyde R. Cameron, MP) referred the question of priorities for the marine sciences to the Interim ASTEC. With the change of government in 1975 and the need to advise the new Prime Minister on the permanent ASTEC, the Interim ASTEC's review did not proceed beyond a draft report that was given limited circulation. The permanent ASTEC has set up a Working Party on Marine Sciences to review the whole area (including the marine technologies of coastal and ocean engineering). ASTEC's interim recommendations and the future of its Working Party are outlined in Chapter 7, Volume 1A of this Report.

21.1.6 Although, in recent years, governments have come to recognise the importance of the marine sciences, no explicit policy guidelines or objectives exist for the marine sciences as a whole. However, an implicit set of policies for the marine sciences can be seen in the Commonwealth's establishment and support of the CSIRO Division of Fisheries and Oceanography, of the Australian Institute of Marine Science (AIMS), of the marine science activities of the Bureau of Mineral Resources, of the Queen's Fellowships in Marine Science, and of the earmarking for the marine sciences of some Australian Research Grants Committee (ARGC) funds in the period 1973-75. There are, additionally, explicit as well as implicit policies for particular aspects of the marine sciences and there are policies on non-scientific aspects of the marine environment that have implications for the marine sciences. Activities and legislation illustrating these are:

- . The Fishing Industry Research Trust Account, the Fisheries Development Trust Account and the well-established roles of the Commonwealth Government and State Governments in fisheries research;
- . Australia's membership of several international fishery organisations;
- . Commonwealth Government establishment of the Great Barrier Reef Marine Park Authority;
- . the Commonwealth Government's decision, in 1977, to expand its Antarctic research into the marine sciences area;
- . Australia's membership of the United Nations' Intergovernmental Oceanographic Commission (IOC);
- . the development of legislation for protection of the marine environment including proposals to ratify the Intergovernmental Maritime Consultative Organisation's (IMCO) London Dumping Convention 1972;
- . the Petroleum (Submerged Lands) Legislation; and
- . Australia's involvement in the current United Nations Conference on the Law of the Sea.

21.1.7 For fisheries research there is no explicit statement of policy, but mechanisms exist for co-ordinating State and Commonwealth activities, and these activities are, in effect, an expression of an implicit set of objectives for State and Commonwealth policy. Though there is no formal review process, the results of fisheries research are considered in terms of their practical implications for fisheries management. For non-fisheries marine biology R&D there are neither government policies nor means for establishing them and hence there is no review of the effort. However, the Australian Marine Sciences Association, whose membership is weighted towards marine biology, develops and puts forward suggested policies on particular aspects of the marine sciences from time to time.

21.1.8 Under current Commonwealth/State arrangements, primary responsibility for off-shore petroleum exploration policy lies with the State Governments. However, under new arrangements to be implemented, the States will have sole control of the seabed inside the three nautical mile territorial sea, while beyond three nautical miles joint Commonwealth/State authorities will be established to replace existing arrangements for off-shore mining for petroleum, and also to cover other minerals in the off-shore area. Commonwealth encouragement to off-shore exploration is given through general incentives; decisions on off-shore exploration initiatives and the review of these decisions are made by the private sector on the basis of the potential returns on capital invested. There is no government policy specifically developed for marine geoscience not concerned with exploration, but the Consortium for Ocean Geosciences of the Australian Universities (COGS) is seeking the development of a national policy and has made a number of submissions to the Government.

21.1.9 Civilian oceanography is not the subject of any policy and no mechanism for policy development or review exists. However, defence marine R&D, which is largely applied oceanography, is planned and reviewed on the basis of defence policy objectives.

21.1.10 Government policies for marine environmental R&D have not yet been established but a mechanism for policy development, implementation and review exists in the form of the Australian Environment Council which is conscious of the importance of the marine environment.

21.1.11 There are very few agreements or arrangements concerning marine R&D activities between the various sectors of the Australian community or between organisations. The Commonwealth and State Governments have arrangements affecting fisheries research and, until recent years, there was Commonwealth legislation providing subsidies for off-shore oil and gas exploration by the private sector. Commonwealth encouragement to off-shore petroleum exploration is currently given through taxation and other incentives. The arrangements associated with the Technical Committee on Oceanography (which is serviced by the Bureau of Mineral Resources, Geology and Geophysics of the Commonwealth Department of National Development), are concerned with the collection and dissemination of information on all vessels in Australian waters which may provide facilities for marine scientists, and with the allocation of Australian vessel time to Australian scientists wishing to work at sea.

21.1.12 Agreements and arrangements dealing with international co-operation in the marine sciences are those under which:

- . the Commonwealth is a member of the United Nations' Intergovernmental Oceanographic Commission (IOC), the Food and Agriculture Organisation of the United Nations (FAO) and the International Whaling Commission (IWC): it is also supporting some fishery programs of the South Pacific Commission, and intends to support the interim office of the South Pacific Regional Fishery Agency;
- . the Australian Academy of Science participates in the International Council of Scientific Unions' (ICSU) Scientific Committee for Oceanic Research (SCOR);
- . the CSIRO Division of Fisheries and Oceanography maintains close contact with the New Zealand Institute of Oceanography and the French institution ORSTOM in Noumea, with the object of exchanging information, and, as far as possible, co-ordinating the Division's research programs with theirs;
- . the BMR engages in exchange of data, and joint planning, in the field of marine geoscience with overseas government and non-government oceanographic bodies.

21.1.13 Australia's participation in the IOC is co-ordinated by the Department of Foreign Affairs on the advice of the National Advisory Committee on International Aspects of Oceanography (NACIAO). The membership of NACIAO used to comprehend both relevant Commonwealth Government agencies and representatives of the academic community, but in recent years only Government agencies have been involved in its deliberations.

21.1.14 The Australian Academy of Science participates in SCOR through its Australian National Committee for Oceanic Research (ANCOR), whose functions are to maintain contact with SCOR and to advise the Academy's Council on Australian participation in the work and affairs of SCOR. ANCOR has about 10 members of whom one represents the Royal Australian Navy (RAN) Hydrographer and another the Australian Marine Sciences Association; the rest are marine scientists drawn from the general academic community. Co-operative marine R&D does take place from time to time under specific bilateral agreements, but it forms only a small part of the total activities under those agreements, although co-operative ventures with West German research vessels during 1977 and 1978 will involve expenditure of some \$3million.

21.1.15 The continuing United Nations Conference on the Law of the Sea is attempting the revision and development of international law dealing with access to the oceans, and exploitation of the resources of the sea and the seabed. The most important issue before the Conference, from the point of view of the marine sciences, is the proposal that an exclusive economic zone extend 200 nautical miles from every coastal state. Though major difficulties remain in some other important areas of the Conference negotiations, consensus is now within reach on this issue. The consensus that is emerging would provide for coastal states having within their exclusive economic zones:

- . sovereign rights over the resources of the sea and seabed;
- . jurisdiction over artificial islands, installations and structures;
- . jurisdiction over marine scientific research; and
- . jurisdiction for the purpose of marine environmental protection.

It now appears likely that, before marine scientific research can be conducted within a coastal state's exclusive economic zone, the consent of that coastal state will have to be obtained. The responsibilities for fisheries and environmental protection that have emerged, or are likely to emerge, from the Conference will increase the need for marine scientific research.

ORGANISATION

21.1.16 With the exception of fisheries research, which is reasonably well-organised, the marine sciences do not have a coherent framework of organisation. The only body that seeks to embrace the interests of all Australian marine scientists is the Australian Marine Sciences Association, which is essentially the professional association of Australian marine scientists and has some 400 members. Marine biologists appear to be the best represented in the Association. All other organisations deal only with some aspects of the marine sciences. For example, while the Australian Institute of Marine Science Act 1972-73 gives AIMS freedom to carry out research in the marine sciences without qualification as to type or location, AIMS is, for the foreseeable future, committed largely to marine biology and the Great Barrier Reef area. Even CSIRO's long-established Fisheries

and Oceanography Division does not cover the marine geosciences. It is too early to tell how the Victorian Institute of Marine Sciences will develop.

21.1.17 Leaving aside off-shore exploration for petroleum and minerals the Commonwealth is both the biggest source of funds for marine R&D and the biggest user of such funds. The major performers of marine R&D are: the CSIRO Division of Fisheries and Oceanography; the Bureau of Mineral Resources, Geology and Geophysics (BMR); the universities as a group; the State fisheries organisations as a group; the Defence Science and Technology Organisation's RAN Research Laboratory; the Australian Institute of Marine Science; the Roche Research Institute of Marine Pharmacology; and the State environment and conservation agencies as a group. A number of CSIRO Divisions have some involvement in the marine sciences but only one, the Division of Fisheries and Oceanography, is primarily concerned with this field of study. Applied Ecology Pty Ltd is a company owned by the Commonwealth Government, and was established to undertake R&D which would enable aboriginal and island people to make better use of the resources of their natural environment. It has been estimated that some 900 scientists are engaged in marine R&D in Australia. Nearly all of these are engaged in on-shore or near-shore studies. A significant, but unknown, proportion of those studying marine organisms are using them purely out of convenience for experimentation rather than because of an interest in marine biology.

FUNDING

21.1.18 Expenditure estimates in this Chapter are based on a recent survey of relevant organisations and individuals and are shown in detail in Table 21.1. Expenditure on R&D associated with exploration for off-shore petroleum and minerals is dealt with separately in paragraphs 21.3.15 and 21.3.16. The coverage of this survey is estimated at 85% of Australian marine R&D. It must be emphasised that although some of the figures are fairly accurate, several, such as the distribution of university R&D over the various fields, are estimates based partly on factual information and partly on the judgement of people familiar with the marine sciences in Australia. The purpose of Table 21.1 is to indicate the general level of annual expenditure in recent years rather than to give a detailed account of expenditure in any particular year.

21.1.19 If off-shore exploratory drilling is accepted as marine scientific R&D, and there are arguments for and against this, this activity, which together with other associated R&D currently costs nearly \$30million annually, represents by far the greatest investment and most economically important marine science in Australia. It is not international practice in discussing R&D expenditure to include such exploration but, given that it can be seen as R&D and given its magnitude, its cost needs to be recorded in this Report.

21.1.20 There are only four granting schemes open to marine scientists in Australia and two of these (the Fishing Industry Research Trust Account and the Fisheries Development Trust Account), representing about 60% of grant monies used in the marine sciences, are tied to fisheries research. Of the other two (the Australian Research Grants Committee

(ARGC) and the Queen's Fellowships in Marine Science Committee) only the Queen's Fellowships are directed specifically at the marine sciences. This latter scheme is designed to attract applications from all nationalities for up to eight postdoctoral awards each year. Although it is possible for AIMS to provide funds for the marine sciences generally, it is unlikely that this will be done in the foreseeable future. With the exception of the tertiary education sector, which is financed by the Commonwealth, there is virtually no cross-funding between sectors. The bulk (over 80%) of university expenditure in the marine sciences is funded from Commonwealth grants to the universities on the advice of the Tertiary Education Commission.

MAJOR R&D AREAS

21.1.21 Expenditure on R&D in the marine sciences is currently between \$20million and \$25million per annum. In arriving at this estimate the following have been excluded:

- off-shore oil and gas exploration R&D - about \$30million in 1976, although the estimate provided by the Department of National Development for the average value over the ten years 1967-76, expressed in 1976-77 dollar values, is about \$90million annually (the latter figure includes the total expenditure on exploratory drilling);
- the hydrographic work of the Royal Australian Navy and the Division of National Mapping of the Department of National Development - about \$5.7million annually, which is not strictly marine sciences R&D;
- defence marine R&D - about \$3.7million annually, the results of which are not widely available to the civilian scientific community.

The Commonwealth provides about 66% of all funds, and spends over 40%, the rest being spent by the universities; the States provide and spend nearly 25%; and industry provides and spends about 10%.

21.1.22 Fisheries and marine biology are the two principal fields of R&D, representing about 30% and 25% respectively of marine R&D expenditure. The next two major fields are oceanography (nearly 25%) and the marine geosciences (about 12.5%). Defence marine R&D expenditure falls between those on oceanography and the marine geosciences. From amongst these various fields, R&D concerned with environmental matters represents about 15% of total expenditure and consists mainly of chemical oceanography and ecology.

21.1.23 There is no area of the marine sciences in which Australia's R&D effort could be described as leading the world or even as being of quite outstanding quality. The work of a number of Australian marine scientists is of a reasonable standard but often, and this is particularly so in the universities, the size of research groups is below that required for the efficient conduct of research.

TABLE 21.1

ESTIMATED ANNUAL MARINE SCIENCES R&D EXPENDITURE IN RECENT YEARS (\$'000)

Performer	Commonwealth					States				Private Sector	Universities	Total		
Field	CSIRO	AIMS	BMR	Applied Ecology	Other	Fisheries Departments	Environment and Conservation Departments	Geological Surveys	Museums			\$'000	% of Major Field	% of Total
MARINE BIOLOGY														
Biology of Organisms	-	-							350		1100	1450	27	
Ecology - estuarine & coastal	750	860							15		350	1975	37	
- reef	40	500							170	710	13			
- environmental protection	-	-				300	780				130	1210	23	
SUB-TOTAL												5345	100	24
LIVING RESOURCES														
Fisheries	-			-	-	-			-		100	100	1	
- exploration	850			-	400	500			140		-	1890	29	
- description	410			-	-	1000			-		-	1410	22	
- assessment	1500			-	25	525			-		-	2050	31	
Aquaculture	-			700	-	300			-		80	1080	17	
SUB-TOTAL												6530	100	30
Pharmacology									1900		110	2010		9
MARINE GEOSCIENCES														
Estuarine & coastal geosciences			100				-	250			900	1250	45	
Ocean geosciences			690				-	125			300	1115	40	
Environmental geosciences (coastal)			-				200	-			200	400	15	
SUB-TOTAL												2765	100	13
OCEANOGRAPHY														
Physics-Chemistry	1800	-			25						1000	2825	58	
Biology	150	300			-						-	450	9	
Environmental (pollution/metals/meteorology)		250			140	110	650				450	1600	33	
SUB-TOTAL												4875	100	23
TOTAL	5500	1910	790	700	590	2735	1630	375	365	2040	4890	21525		100
SECTOR TOTAL			9490				5105			2040	4890			

DEFENCE R&D

The expenditure appearing below has not been included in the main part of this Table because its results are not widely available to the civilian scientific community so that it does not contribute to the general body of scientific knowledge. The \$100,000 under ocean geosciences is the estimated cost of ship-time made available to university geoscientists by the RAN Hydrographer.

<u>Field</u>	<u>Expenditure</u>
Ocean geosciences	100
Basic oceanography	240
Applied oceanography	3360
SUB-TOTAL	3700

ENVIRONMENTAL STUDIES

The following items have been regrouped from the main part of the Table to give an indication of the extent of environmental studies R&D.

<u>Field</u>	<u>Expenditure</u>
Ecology	1210
Geosciences	400
Oceanography (pollution/metals/ meteorology)	1600
SUB-TOTAL	3210

ECONOMIC GEOLOGY

These activities have not been included in the main part of the Table because there are conflicting views whether off-shore exploration is really scientific R&D, and because the magnitude of the expenditure involved would have made the percentages columns less useful.

<u>Field</u>	<u>Expenditure</u>	
	State geological surveys	Private Sector
Hydrocarbons	-	29400
Mining	75	90

HYDROGRAPHY

The work by the RAN Hydrographer's Office and the Division of National Mapping of the Department of National Development is not strictly R&D, but rather an associated activity essential to scientific R&D as well as to other activities.

	<u>Expenditure</u>	
Defence		Other Commonwealth
4900		775

21.1.24 As one of the few developed countries with a tropical marine environment, and with access to and control of the unique Great Barrier Reef, Australia has an opportunity to make a significant contribution to the world's knowledge and understanding of tropical and reef systems. The establishment of the Australian Institute of Marine Science (AIMS) near Townsville was designed, in part, to meet this challenge, but the Institute has still not reached its minimum establishment size. Australia is also one of only two developed countries bordering both the Indian Ocean and the southern oceans. Though Australia made a contribution to the International Indian Ocean Expedition, very little has been done in this area since. A very recent development is that an Australian program for Antarctic marine sciences is planned.

21.1.25 Particularly weak areas of marine science are civilian oceanography and the marine geosciences, largely because these disciplines are particularly dependent on ocean-going research vessels of which Australia owns none. There are only three university groups specifically concerned with the marine sciences (the Marine Studies Centre, University of Sydney; Flinders Institute for Atmospheric and Marine Sciences, Flinders University of South Australia; and Committee on Marine Science, University of Melbourne) and so training in the marine sciences both at the undergraduate and postgraduate level is poorly catered for.

VESSELS

21.1.26 Table 21.2 summarises the availability for research of vessels of more than seven metres in length. Because Australia does not own any civilian research vessels above 30 metres in length, and since a length of at least 40 metres is needed for satisfactory open-ocean work, Australian scientists are not able to conduct any deep water research, except through intermittent access to defence vessels and through the use of chartered vessels by organisations such as CSIRO. Some alleviation of this situation will occur in the near future. AIMS is soon to take delivery of a 24-metre marine biology/oceanography research vessel which, though too small for oceanic R&D, will increase AIMS' research capacity. HMAS Cook, a classical oceanography vessel of 90 metres, to which civilian scientists may have some access, is due for completion in late 1980. The CSIRO has for some time had a proposal before the Government for a 54-metre oceanographic research vessel. The Government has provided \$100,000 in 1978-79 for a design and planning study for an Australian Antarctic relief vessel, which is to incorporate a marine sciences capability. It is also planned to replace the CSIRO 28 metre chartered research vessel 'Courageous' with a chartered 50 metre fisheries research vessel. However, even if all these vessels become available, Australia would still not have any ocean-going marine geosciences vessels.

TABLE 21.2

VESSELS OF 7M. LENGTH OR MORE ENGAGED IN
MARINE SCIENCE IN AUSTRALIA

(Vessels to become operational in 1978 are included)

	Length (metres)							
	7 to 10	10 to 15	15 to 20	20 to 30	30 to 40	40 to 50	over 50	Total
Commonwealth								
Defence						1	1	2
CSIRO		2	1	1c		1c		5
AIMS	3	2		1				6
Applied								
Ecology	4	1		1				6
								<u>19</u>
States								
Fisheries	4	2		5				11
Other	4	4	2					<u>10</u>
								<u>21</u>
Universities	1	3	2	1				7
Total	16	14	5	9		2	1	47

c : chartered for a long period

21.2 MARINE BIOLOGY, INCLUDING FISHERIES

DEFINITION OF AREA COVERED

21.2.1 Marine biology comprehends the study of all living marine organisms both as individuals and as components of living communities interacting with their environment. Hence, the taxonomy, physiology and distribution of individual marine species are studied, as is the ecology of estuarine, coastal, and reef communities. Particularly important is the interaction of these communities with mankind through such things as people's recreational and food needs, the biodegradation of wastes and the biocycling of natural and man-made materials that are harmful to man. Oceanic work of a similar nature has been included under the category 'Oceanography' because many aspects of oceanic marine biology have to be closely integrated with physical and chemical studies of the open ocean, and because they are dependent on the availability of ocean-going research vessels.

21.2.2 The application of marine biology to the problem of exploiting the living resources of the marine environment is also included within this section. Fisheries research is the major activity of this type and includes such things as:

- . exploration for currently unfished species to obtain data on additional resources which may be available;
- . description of species already being fished as to their abundance, distribution and general biology; and
- . assessment, by more precise and quantitative studies, of the relation between the harvest currently being taken from the resource and the optimum catch.

Fisheries development is seen as the application of the results of fisheries research in the development of management advice for existing fisheries, in the establishment of new fisheries on newly discovered resources, and in the introduction of new techniques to improve the quantity and composition of the catch.

21.2.3 Aquaculture R&D to develop improved farming techniques for cultured species such as oysters is a smaller field than fisheries research, and another, much less familiar to most people but of significance in Australian marine sciences, is the investigation of the usefulness in human pharmacology of chemicals derived from marine organisms.

POLICIES, AGREEMENTS AND ARRANGEMENTS

21.2.4 With the exception of fisheries research, there are no explicit policies or agreements operating over and above those of individual organisations in the marine biology area.

21.2.5 The common-property nature of fisheries necessitates a high degree of government involvement in the fishing industry and results in the practice, common to most rural industries, of heavy government involvement in R&D. The Commonwealth and State Governments have an obligation to manage the resources of Australia's fisheries for the benefit of the whole Australian community and this imposes a requirement that, although exploitation may be encouraged, it should be contained at a level that can be sustained. To this end, the objectives of fisheries research can be regarded as:

- . the acquisition of an understanding of the biology of exploitable species (particularly their distribution and abundance);
- . an understanding of the effects of exploitation on the resource;
- . the determination of efficient methods of exploitation; and
- . the determination of the quantity and composition of the optimum catch available from existing and potential fisheries.

21.2.6 Although the Commonwealth and the States have generally similar attitudes towards research objectives, there is much less consistency of attitude in the way in which management policies are formulated. Different fisheries have different significance to different communities and to the different levels of government; their management is not associated solely with biological considerations but takes account also of economic, social and political considerations, all of which vary from State to State. Furthermore, these latter aspects are constantly changing so that the relative importance of individual fisheries changes with time both within a State and between States (or between the States and the Commonwealth). In response to this, requirements for fisheries research in specific fisheries change from time to time, sometimes quite quickly.

21.2.7 Since the 1950's there has been a change in Commonwealth and States fisheries research policies so that the States, which had previously been fairly inactive in fisheries research, began expanding their activities especially in exploratory fishing. At the same time, the then Division of Fisheries of CSIRO moved away from research pertinent to particular States to work on national fisheries problems. It was during this period of change in the early 1960's that the present system of co-ordination of Commonwealth and State fisheries research activities was inaugurated.

21.2.8 Co-ordination of Commonwealth/State Government activities in fisheries is now undertaken through a complex structure of committees centred on the Australian Fisheries Council. The Council consists of the Commonwealth and State Ministers responsible for fisheries and the Minister for Science. The subordinate committees are composed of appropriate officials. The work of the Council and its main subordinate committee, the Standing Committee on Fisheries, is mainly concerned with general problems of fisheries management and with the co-ordination of activities between the Commonwealth and the States, and between adjacent States. There is a further level of sub-committees most of which are primarily involved with the co-ordination of scientific programs and with discussion of their results in terms of practical management.

21.2.9 Under the Constitution the Commonwealth is responsible for fisheries legislation beyond territorial limits. However, in practice, the allocation of responsibility for fisheries research is not determined so much by the legal situation, but rather is worked out through the Australian Fisheries Council and its sub-committees. The State fisheries agencies maintain a number of committees to facilitate consultation with the fishing industry. Much of their work is devoted to questions of management, but they also assist research by identifying problems and promoting the voluntary collection of data.

21.2.10 In its Report on Financing Rural Research[2], and its Draft Report on Harvesting and Processing of Fish, Crustaceans and Molluscs[3], the Industries Assistance Commission (IAC) made a number of observations and recommendations about the level of expenditure on fisheries research and about the relation of this to the level of assistance to, and the efficiency of, the fishing industry. These issues are outlined in paragraphs 21.2.37 to 21.2.39 which deal with the funding of fisheries research.

21.2.11 As a result of international developments arising from the United Nations Conference on the Law of the Sea, the Commonwealth Government has decided to establish a 200 nautical mile, Australian Fishing Zone (AFZ). The necessary amendments to the Fisheries Act 1952 have received Royal Assent and the Zone will be proclaimed in the near future. In anticipation of this development, the Australian Fisheries Council formed a working group, in early 1977, to consider and report on the management needs that the establishment of such a zone would create. Those terms of reference for the group that are of particular interest here are the requests that it consider:

- . the size and status of stocks within the 200-mile zone;
- . the problems of ascertaining a total allowable catch and the surplus available to other nations;
- . the means of arriving at estimates of total allowable catch; and
- . the responsibilities of the Commonwealth and State fisheries organisations in managing the resources of the zone.

The working group's report [4] was submitted to the Australian Fisheries Council and is now generally available. It does not address the issue of the research requirements that will be created by the establishment of the Zone. However, the Government recently decided to make available \$700,000 in 1978-79 to meet the immediate need to strengthen the resource management staff of the Fisheries Division of the Department of Primary Industry, and to enable CSIRO to provide research support for the management of the resources of the 200-mile AFZ.

21.2.12 Australia is a member of: the United Nations Food and Agriculture Organisation and its regional fisheries advisory bodies, the Indo-Pacific Fisheries Commission (IPFC) and the Indian Ocean Fisheries Commission (IOFC); the International Whaling Commission; and the South Pacific Commission and South Pacific Forum. All these bodies have some involvement with fisheries research.

ORGANISATION

21.2.13 The major performers in the area of non-fisheries marine biology are the universities, the Australian Institute of Marine Science (AIMS), the Roche Research Institute of Marine Pharmacology, the CSIRO Division of Fisheries and Oceanography, the State environment and conservation authorities and the State museums.

21.2.14 Fisheries research is carried out by the CSIRO Division of Fisheries and Oceanography, the State fisheries organisations and, to a lesser extent, the fishing industry. The primary users of the results of fisheries research are the government agencies responsible for fisheries management; the industry is in a sense a secondary user.

21.2.15 The CSIRO Division of Fisheries and Oceanography was established in the 1930's as the Division of Fisheries, but its

responsibilities were extended in the late 1950's to include other aspects of marine science, though not marine geosciences. The Division has a total staff of about 150 of whom 66 are professional research personnel, and an annual operating budget of \$5.5million. It has a central laboratory in Cronulla, Sydney, and regional laboratories near Perth and Brisbane, as well as a field station at Karumba on the Gulf of Carpentaria.

21.2.16 The general policy of the Division in fisheries matters is to undertake a small number of projects, each of which is concerned with a fishery of major national importance. At present the Division has two programs concerned with fisheries problems, one of which deals with commercially important fish. The largest section of this program involves surveys of the fish resources of the continental shelf and adjacent seas, and other major components are concerned with tuna, Australian salmon, and fish taxonomy. The other fisheries program is concerned with crustacea and has two components: that in the Perth laboratory is concerned with western rock lobsters, and is being conducted in close co-operation with the Western Australian Department of Fisheries and Wildlife; the second involves work on the prawns of the Gulf of Carpentaria. In addition to fisheries, the Division's main areas of interest at present are: the biology of marine organisms, both individually and in communities; chemical aspects of oceanography; and the nature and mechanisms of water circulation, both inshore and in the open ocean.

21.2.17 The primary objective of AIMS is to carry out research in the marine sciences. It is managed by a Director under the guidance of a part-time Council appointed by the Minister for Science and has very wide powers. It was established in 1974 and is still in the establishment phase of its development. It currently has a budget of about \$2million and a staff of about 66, of whom 17 are professional research workers.

21.2.18 The work of AIMS is largely directed towards tropical marine problems and much is of a fundamental nature. The largest program is concerned with the productivity of inshore tropical communities and is at present largely oriented towards mangrove systems. The Institute is also investigating coral reef problems and current programs include studies of coral taxonomy and of calcification processes. It is also studying the dynamics of tropical plankton, particularly from the point of view of marine food chains. It also has a study on pollution problems in tropical seas. All AIMS programs are at present undertaken within a convenient distance of its laboratory near Townsville.

21.2.19 The Antarctic Division of the Department of Science has not been active in the marine sciences, but in 1977 the Government announced that a marine sciences program with considerable emphasis on marine biology is to be initiated over the next few years.

21.2.20 The CSIRO, AIMS and the Antarctic Division are all responsible to the Minister for Science. There is no formal co-ordination of their activities, but AIMS' charter was developed in the light of CSIRO's role and similarly the Antarctic Division's role will be developed in the light of the others.

21.2.21 Applied Ecology Pty Ltd is a company wholly owned by the Commonwealth Government. It was established for the purpose of

undertaking R&D which would assist the aboriginal and island people to make improved use of the available natural resources in a manner consistent with their existing way of life. The major part of the current program is aimed at exploring the possibilities of turtle farming by Torres Strait Islanders. The company is at present at a holding level of operation because of the Government's financial restrictions on the public sector, but it sees a continuing role for itself in the marine area.

21.2.22 The Fisheries Division of the Commonwealth Department of Primary Industry discharges the Commonwealth's management responsibilities in regard to fisheries. The Division employs a few biologists in advisory roles but does not undertake biological research although it administers some funds which support research. The Division relies heavily on the CSIRO Division of Fisheries and Oceanography for technical advice. The Fisheries Division does, however, undertake and finance exploratory and experimental fishing aimed at the development of new fisheries.

21.2.23 The States' responsibilities for fisheries lie with the following State Departments:

New South Wales - Department of Fisheries

Western Australia - Department of Fisheries and Wildlife

South Australia - Department of Agriculture and Fisheries

Tasmania - Tasmanian Fisheries Development Authority

Victoria - Ministry for Conservation

Queensland - Department of Aboriginal and Islander Advancement

Northern Territory - Department of Industrial Development

21.2.24 The primary responsibility of the State agencies is the formulation of fisheries policies and their execution through the management of the fisheries under their jurisdiction. All State fisheries agencies maintain scientific sections whose task is to study the local resources so as to provide the necessary advice for management. The research undertaken by these bodies is normally directed towards immediate practical objectives and the solution of problems arising in the day-to-day management of the fisheries. Consequently, effort is normally distributed over a considerable number of projects. Most State fisheries organisations also undertake some work in connection with the protection of the marine environment.

21.2.25 A major component of State fisheries research, with the exception of the Northern Territory, is exploration of fisheries resources. This is mainly off-shore in New South Wales, Victoria and Tasmania, and mainly inshore in Queensland, South Australia and Western Australia. The other major focus of attention is lobster biology and assessment off the coasts of Western Australia (particularly), South Australia and Tasmania. New South Wales devotes considerable resources to oyster culture and Queensland has a substantial effort in studies of the Great Barrier Reef. The Northern Territory's main research interest is with prawns.

21.2.26 The approximate expenditure and professional staffing of these fisheries agencies is set out in Table 21.3.

TABLE 21.3

APPROXIMATE EXPENDITURE AND NUMBERS OF PROFESSIONALLY-
QUALIFIED STAFF IN STATE FISHERIES ORGANISATIONS

	NT	NSW	Qld	SA	Tas	Vic	WA
<u>Approximate Staff and Funds</u>							
Professional Staff	3	35	15	10	5	5	15
Expenditure (\$'000)	105	600	342	500	313	366	685

21.2.27 The principal State museums all conduct a significant amount of marine biological research. Nearly all their work is concerned with the taxonomy and the distribution of the marine flora and fauna of the coastal region and the adjacent seas. Museums with the largest programs are the Western Australian Museum, the Australian Museum in Sydney and the Queensland Museum.

21.2.28 The Victorian Institute of Marine Sciences (VIMS) was established by the Victorian Parliament in late 1974 under legislation which gives it a legal status similar to that of the universities. The Institute is governed by a Council, which is made up of representatives of the relevant Victorian Government agencies and of the Victorian universities, and has provision for other categories of representation. It hopes to attract funds from a wide variety of sources, including the Commonwealth Government. The Victorian Government has provided VIMS with a site at Queenscliff and will provide \$200,000 in 1978-79 towards the cost of a study of Bass Strait.

21.2.29 To some extent the Institute resembles AIMS and CSIRO in that its enabling Act gives it great freedom in the R&D it can undertake (R&D in all branches of learning concerning or touching upon the marine sciences). However it differs from these bodies in that it is to provide facilities for teaching and is intended to collaborate closely with other institutions in both research and teaching. In particular, it is to be closely related to the Marine Laboratory of the Ministry for Conservation in Victoria and to educational bodies.

21.2.30 Nearly half the university research projects in the marine sciences, representing about one-third of university marine research expenditure, are in the field of marine biology and related environmental studies. Most of the nation's universities sponsor continuing programs, with the largest programs being concentrated in the University of Melbourne, the James Cook University of North Queensland and the University of New South Wales. About 100 academic scientists are involved in marine research and teaching. In the biological sciences, virtually the only research of an applied nature is that dealing with environmental protection, and there are only three current fisheries projects.

21.2.31 There is only one major institution for marine biological research which is operated by an industrial concern. The Roche Research Institute of Marine Pharmacology, near Sydney, was established in 1974 by Hoffmann La-Roche of Switzerland, to seek useful pharmacological products of marine origin in the Australian area. This relatively large and highly specialised organisation has about 22 professional staff and an annual operating budget of about \$2million.

FUNDING AND DESCRIPTION OF MAJOR R&D PROGRAMS (NON-FISHERIES)

21.2.32 There are no separate granting schemes for non-fisheries marine biology, each organisation providing its own funds and individual scientists seeking additional support from such general sources as the Australian Research Grants Committee (ARGC). During the 1973-75 period the ARGC had a proportion of its funds earmarked for the marine sciences but this was discontinued when it was felt that the quality of applicants had risen to the point where they could compete for the ordinary funds.

21.2.33 Excluding the Roche Research Institute of Marine Pharmacology, whose work is primarily directed at human pharmacology, nearly all marine biological research is funded ultimately by the government sector: about 75% by the Commonwealth and the rest by the States. About 40% of the Commonwealth's share is represented by university funding.

21.2.34 As Table 21.1 shows, annual expenditure on marine biological research is about \$6million and the major areas of research are: estuaries and coastal ecology (nearly 40%); the biology of individual organisms (over 25%); and environmental protection ecology (nearly 25%). About 75% of the research on individual organisms is conducted by the universities, but much of this work is only incidentally marine science because the organisms are chosen for their convenience in studying particular processes rather than because of their marine habitat.

FUNDING AND DESCRIPTION OF MAJOR R&D PROGRAMS (FISHERIES)

21.2.35 Table 21.4, which has been taken from the Industry Assistance Commission's (IAC's) Draft Report on Harvesting and Processing of Fish, Crustaceans and Molluscs[3], shows that the Commonwealth (principally the CSIRO Division of Fisheries and Oceanography) and the State Fisheries agencies are the two major sources of funds for (about 70% and 20% respectively) and performers of (about 60% and 33% respectively) fisheries research.

21.2.36 There are two granting schemes for fisheries research: The Fishing Industry Research Trust Account (FIRTA) and the Fisheries Development Trust Account (FDTA) both of which are administered by the Commonwealth Department of Primary Industry. Together they contribute between 10 and 15% of fisheries research funds. The objectives specified in the respective Acts for the two schemes are basically similar, but FIRTA is used for projects concerned with basic research and existing fisheries while FDTA is generally used for projects directed towards development of new fisheries or techniques.

TABLE 21.4

ESTIMATED FISHING RESEARCH AND EXPLORATION
EXPENDITURE IN AUSTRALIA, 1973-74 (\$'000)(a)

(Taken from Draft IAC Report on 'Harvesting and Processing of Fish, Crustaceans and Molluscs')

<u>Source of Funds</u>	<u>RESEARCH AGENCIES</u>					% of Total Funds
	Cwlth Govt	State Govts	Higher Education	Business Enterprise	Total	
FIRTA(b)	146	261	-	20	426	68
FDTA(c)	170	98	-	95	364	
Other Cwlth Govt sources	3622(d)	168(e)	69(f)	10(g)	3869	
State Govt	-	1406(h)	1(f)	-	1407	
Private sources	-	417(j)	15(f)	330(k)	762	11
Total(l)	3938	2350	85	455	6828	100

- a. Discrepancies between the component amounts and the totals are due to rounding.
- b. Fishing Industry Research Trust Account. Source: Department of Primary Industry unpublished data. The figures presented are actual expenditures of FIRTA in 1973-74 and are not necessarily equivalent to the grants approved in that year.
- c. Fisheries Development Trust Account. Source: 'Eighteenth Annual Report of the Operations of the Fishing Industry Act 1956'. The figures shown are actual payments during 1973-74, rather than the grant amounts. The distribution varies greatly from year to year.
- d. This amount is the difference between the total expenditure of Commonwealth agencies and the expenditures from FIRTA and FDTA.
- e. This is the amount paid to the State governments through the Shark Fishermen's Rehabilitation Scheme.
- f. Source: unpublished survey data from the Commission's inquiry into 'Financing Rural Research'. For reasons stated in the Commission's report 'Financing Rural Research', the expenditure of higher educational institutions may be understated.

- g. Source: Report of the Australian Industrial Research and Development Grants Board, 1973/74.
- h. This amount is the residual after funds from other sources have been deducted from State Government agencies' total expenditure.
- j. This figure is the Commonwealth Government's contribution to FIRTA, as given in the Annual Report of the Fishing Industry Research Committee, 1974-75. It is assumed that this is equal to the amount paid by industry, through fishing licences, into 'approved research funds'. This amount may differ from the actual expenditures from these funds in that year.
- k. This amount is the residual after funds from other sources have been deducted from the Business Enterprises total. Due to the difficulties involved in obtaining a complete coverage of private research expenditure, much of which is undocumented, Business Enterprises expenditure may be understated.
- l. Figures in this row are from Table 3.3 of the Commission's draft report on 'Financing Rural Research' [2].

21.2.37 FIRTA funds consist of Commonwealth moneys equivalent in amount to the specified funds levied on the industry by the individual States for research purposes and paid into State-established 'approved research funds' by State governments, up to a maximum equivalent to the fishing industry licence fees raised by the States. The levies are collected, controlled and spent by the States concerned, and the FIRTA funds are allocated to Commonwealth, State, university and private enterprise research bodies by the Minister for Primary Industry on the recommendation of the Fishing Industry Research Committee (FIRC) on which the industry is represented. FIRTA funds support between 5% and 10% of total fisheries research. FDTA funds, which are generally less than FIRTA funds, are not related to any industry contribution and are allocated by the Minister for Primary Industry on the advice of his Department. In its Draft Report on Harvesting and Processing of Fish, Crustaceans and Molluscs the IAC has suggested that the FIRTA and the FDTA be amalgamated or that the FIRC be given an advisory role in relation to expenditure from the FDTA. It proposed this because there appeared to be little opportunity for users, in particular, to be involved in choosing research projects funded from the FDTA and because expenditure from the two funds can be used for similar purposes.

21.2.38 Fisheries research, which consists of about 30% each of fisheries exploration and assessment, about 20% fisheries description, and about 20% aquaculture, is the biggest single research area in the marine sciences, costing between \$6million and \$7million annually. Table 21.1 suggests an annual expenditure of about \$6.5million, and the IAC's Report on Financing Rural Research gave a similar estimate for 1973-74 of \$6.8million (some of which may have been expended on food processing R&D). This R&D expenditure is equivalent to about 6% of the fishing industry's gross product value.

21.2.39 As the IAC has indicated, this proportion is much higher than that for the rural sector as a whole (about 2%). However, the following

points emerge from the IAC's Draft Report on Harvesting and Processing of Fish, Crustaceans and Molluscs:

- . the main form of government assistance to the fisheries sector is government-supported research and exploration expenditure;
- . at least for the most part, the harvesting and processing of fish, crustaceans and molluscs appear to be activities which receive relatively little assistance, and which are relatively efficient users of the community's resources;
- . the lack of ownership or control of fisheries stock makes it difficult to ensure that the benefits from industry expenditure on research and exploration accrue solely to Australian fishermen;
- . in the IAC's view there is no basis for either reducing research assistance to this lightly-protected industry or replacing these research and exploration expenditures with assistance in some other form. Without such assistance there would probably be under-investment in research and exploration;
- . additional expenditure on research and exploration may be considered desirable in the light of changing economic and political circumstances (e.g. establishment of a 200-mile Fishing Zone). The costs of research and exploration, undertaken as a part of international commitments made by government on behalf of the Australian community in general, should not be borne by the industry unless the benefits from it proved to be large and to accrue primarily to the fishing industry.

MANPOWER

21.2.40 Inshore and coastal biologists are the largest group of marine scientists in Australia. This is because their type of research is easy to undertake with limited facilities and because, as a discipline, it is far more diversified than others in the marine sciences. A large proportion of marine biologists and marine environmental scientists have come from overseas, at least in part because of the large number of personnel with experience and training in the UK and USA. The number of marine biologists in Australia is probably large enough now, however, to enable Australia to train marine biologists and to undertake complex projects.

VESSELS

21.2.41 Estuarine and coastal scientists have a large number of small vessels at their disposal: most are used for mission-oriented projects rather than for basic research. Although the Australian Institute of Marine Science is soon to take delivery of a 24-metre marine biology/oceanography research vessel, the major weakness, in all the marine sciences, is a lack of larger vessels for work in deeper waters. Fisheries research in

particular will be inadequately served once a 200-mile fishing zone is established. The CSIRO currently has two vessels on long-term charter (the 28-metre 'Courageous' for fisheries work and the 45-metre 'Sprightly' for oceanographic work) and it is understood that it intends to continue chartering fisheries vessels to meet its needs in the fisheries area; as noted in 21.1.26, it is intended that 'Courageous' will be replaced by a 50-metre research vessel.

TRENDS

21.2.42 The Australian Institute of Marine Science (AIMS) has yet to reach its basic establishment strength, and the Victorian Institute of Marine Sciences (VIMS) is at an even earlier stage of development. Given that the full implications of past decisions have therefore still to take effect, some expansion of marine biological R&D is inevitable.

21.2.43 Current Commonwealth and State fisheries research is based on the needs of the present Australian industry operating with a 12-mile fishing zone, and the establishment of a 200-mile fishing zone will create a new set of research needs. As noted in paragraph 21.2.11, the Ministers for Primary Industry and for Science are currently addressing the most urgent aspects of this problem.

21.2.44 Tentative estimates of the biologically sustainable yield from the fisheries in the 200-mile zone suggest that this yield could range from two to four times the volume of the current catch. However, the fishing industry is small; employment is only about 0.5% of total Australian employment (about 8% of rural employment) and the value of fisheries production is less than 2% of the total gross value of rural production. Consequently, if the local industry were to expand to take full advantage of the potential catch in the 200-mile zone, it still would not approach in size the major rural industries of meat, wool and cereal production.

21.2.45 There is no reason to believe that the universities and museums will not continue their marine biological work at roughly current levels. It is too early to predict what the likely impact will be of the Commonwealth Government's decision to expand its Antarctic research into the marine sciences area and, in particular, into marine biology.

21.3 MARINE GEOSCIENCES, INCLUDING OFF-SHORE EXPLORATION

DEFINITION OF AREA COVERED

21.3.1 The marine geosciences comprise:

marine geology, which deals with the composition, arrangement and origin of the materials (including the superficial sediments) of the continental shelf, the seabed, and their subsurface

layers; and the processes involved in the evolution of their present structures; and

marine geophysics, which is concerned with the structure and physical properties of the materials of the continental shelf, the seabed and the underlying layers.

21.3.2 Investigations may be concerned either with the delineation of the general features of the marine crust or with the more abstract task of developing geodynamic models. While the former are of short-term importance in cataloguing the environment and its resources, the latter may have greater significance in the long-term by providing data and concepts that enable resources to be reassessed. An understanding of the character and evolution of the earth's crust beneath the ocean is very important to global geology and is leading to new approaches to the solution of geological problems on land as well as below the sea.

21.3.3 The area of interest to Australian geoscientists extends from the mid-Indian Ocean to New Zealand and Samoa and from the South-East Asian region to Antarctica. Though this region extends far beyond the limits of Australia's jurisdiction, information about it is essential to a full understanding of the history of our continental margins and to an assessment of their resource potential. Features of particular interest to marine geoscientists include coral reefs, submerged shorelines, submarine canyons, stable and unstable continental and crustal plate margins, and submarine volcanicity.

21.3.4 Commercial, off-shore, oil, gas and mineral exploration is the most important marine geoscience activity, both in terms of its cost and of its potential for economic gain. As has been pointed out previously, there are differing opinions whether this work is R&D or a routine survey activity: it is not included in international comparisons of R&D expenditure.

POLICIES AND AGREEMENTS

21.3.5 Research bearing directly on the economic potential of the sea floor and its subsurface layers is conducted primarily by the private sector and is controlled by the State and Commonwealth Governments through the Commonwealth/State Petroleum (Submerged Lands) legislation and the State Mining Acts. Under the Petroleum (Submerged Lands) Act 1967, the relevant State Ministers, as Designated Authorities, are empowered to issue titles for exploration and exploitation. However, since the High Court decision on the Seas and Submerged Lands Act confirmed the Commonwealth's sovereignty below the low-water mark, future arrangements for off-shore administration have been under discussion in the Premiers' Conference. Under new arrangements to be implemented, the States will have sole control of the seabed inside the three nautical mile territorial sea, while beyond three nautical miles joint Commonwealth/State authorities will be established to replace existing arrangements for off-shore mining for petroleum and also to cover other minerals in the off-shore area. The States will continue to provide the point of contact with the industry. To encourage petroleum exploration the Commonwealth

between 1959 and 1974 offered an exploration subsidy under the Petroleum Search Subsidy Act (1959-1973). Currently the Commonwealth Government has no commercial involvement in off-shore exploration, but provides taxation and other incentives to encourage private exploration.

21.3.6 Internationally, the 1958 Convention on the Continental Shelf gives recognition to Australia's sovereign rights over the continental shelf for the purpose of exploring it and exploiting its natural resources, and also confers rights of control over scientific research conducted on the shelf. If the negotiations at the Third United Nations Conference on the Law of the Sea lead to a comprehensive Convention, coastal states like Australia may also be given control over research on the seabed beyond the continental shelf and out to 200 nautical miles. There are two international groups in the Asia/Pacific region concerned with marine geology: Australia, while not a member, is a consultant to both. These groups are the Co-ordinating Committee for Offshore Prospecting (CCOP) of the Economic and Social Council for Asia and the Pacific (ESCAP), and the CCOP for the South Pacific (SOPAC).

21.3.7 The Commonwealth, through the Bureau of Mineral Resources, Geology and Geophysics (BMR) undertakes its marine research in both coastal and deeper waters, while the State Geological Surveys confine themselves to near-shore work, largely of an applied or environmental character.

21.3.8 As a result of the Royal Commissions into Oil Drilling on the Great Barrier Reef[5], exploration in the Great Barrier Reef area has been temporarily suspended pending research to determine its probable environmental effects.

21.3.9 The Consortium for Ocean Geosciences of the Australian Universities (COGS), which was formed in 1975 and consists of representatives of the earth sciences departments of 16 Australian universities, has as its objectives obtaining access to a research vessel, fostering co-operative research, and participating in the International Program of Ocean Drilling (IPOD). It is endeavouring to involve itself in policy making and co-ordination activities as these develop.

ORGANISATION

21.3.10 As stated earlier, by far the biggest activity in the marine geosciences is commercial exploration for off-shore oil and gas. Commercial ventures operating to recover geological resources from the seabed include: Esso Australia Ltd, and The Broken Hill Proprietary Co Ltd (BHP) in the Bass Strait oil and gas fields and neighbouring areas; and Woodside-Burmah NL, Western Australia Petroleum Pty Ltd (a consortium of five international companies plus Ampol Petroleum Ltd), Shell Company of Australia and several others, operating on the North West Shelf gas discoveries. The interests of those concerned with petroleum exploration are advanced through the Australian Petroleum Exploration Association. Companies have access to BMR data and there is some co-operation between

the private sector and individuals in tertiary institutions. Only two Commonwealth agencies have any significant involvement in the marine geosciences: the BMR through its research, and the Royal Australian Navy (RAN) Hydrographer's Office through the provision of ship-time to civilian scientists.

21.3.11 The primary function of the BMR is to obtain, study, publish and provide basic geological and geophysical information necessary for the exploration and development of the nation's mineral resources. In support of this function experimental studies and research in the earth sciences are carried out. The Bureau also services the Technical Committee on Oceanography which is concerned with the allocation of ship time to marine scientists. Co-operative ventures in marine geosciences are sometimes carried on with State geological surveys, university scientists and foreign institutions, but private studies for industry are not undertaken. Since 1975-76 marine studies (\$692,000 in 1976-77) have constituted about 5% of total annual BMR expenditure, and have consisted mainly of data processing and interpretation. Not included in this figure are the costs of projects in engineering geology and geophysics, sedimentology, and geochemistry, that are concerned with coastal environments, lagoons and estuaries, even though these projects may use boats and marine techniques. Also not included are costs of BMR's effort in basin studies (mainly for petroleum resources assessment), and various regional studies, all of which, to a greater or lesser extent, make use of marine data from BMR and other sources. Prior to 1975-76, marine studies were closer to 10% of total BMR expenditure and, during the two year Continental Margin Survey in 1971-73, ranged up to 20%. Before the Continental Margin Survey, costs were dominated by multi-sensor, underwater geophysical surveys, with an average of 3-months survey every 18 months. Although it has the largest geophysical group in Australia, the BMR has carried out no major geophysical surveys since 1972. However, during 1974 BMR conducted a small seismic survey on the New South Wales shelf, and since 1976 it has carried out magnetometer and seismic surveys off Western Australia. BMR has a small marine geology group engaged in deep sea, outer margin and shelf work. Regional geological reconnaissance of the shelf has been suspended since 1973.

21.3.12 Organisational arrangements within the State agencies are variable but most surveys are within departments of mines. The marine groups are very small. Only in Queensland, in the recent past, have there been extensive joint programs with BMR (on the Great Barrier Reef). State surveys specialise in applied research concerned with ports and harbours and coastal erosion, and this is often carried out at the request of other agencies. State surveys also undertake some basic research on estuaries and the continental shelf and some off-shore mineral exploration work is undertaken, but there is little in the way of co-operative work with tertiary institutions.

21.3.13 Marine geoscience research in universities is an active field of study, but resources are thinly spread, R&D being undertaken in at least 16 universities, and comprising about 33% of all university projects in marine science. Most such work, and associated teaching, is carried out in geology or earth science departments or schools, several of which contribute to an integrated, undergraduate curriculum in marine science (Sydney, NSW, Melbourne, James Cook and Flinders). Marine geoscientists

include geologists, geophysicists, sediment-transport specialists with strong interests in physical oceanography, and biological palaeontologists specialising in reefs, etc. The emphasis is on pure research, but applied and economically important studies are common.

21.3.14 Governmental agencies are mostly mission-oriented and tend to perform their functions independently of other groups. Co-operation is more common in pure-science programs. For these, co-ordination of projects aboard Royal Australian Navy (RAN) vessels is handled by the Technical Committee on Oceanography while the BMR often initiates and organises international programs on visiting foreign ships. In some such cruises, university and museum scientists are included but rarely geoscientists from state agencies. A small degree of co-ordination of university projects arises from encouragement of, or restraints on, major new programs by the Tertiary Education Commission, and from attempts by the ARGC to encourage sharing arrangements for expensive items of equipment. In general, Australian marine geoscience is not extensive enough at present to require a great deal of co-ordination.

FUNDING AND DESCRIPTION OF MAJOR R&D PROGRAMS

21.3.15 By far the largest expenditures in the marine geosciences are made by the oil companies in exploration, development and production activities in Bass Strait and on the Northwest Shelf (see Table 21.5). The average annual expenditure on off-shore petroleum exploratory investigations by private enterprise over the ten years 1967-1976 was of the order of \$90million (in 1976-77 dollars). Although it is not international practice to include such investigations as R&D (even though exploration costs may be considered as analogous to R&D costs), this represents by far the greatest investment and most economically important activity related to marine science in Australia and, given its magnitude, its cost needs to be recorded in this report. Expenditure on exploration amounted to nearly \$30million in 1976. In addition, exploration subsidies from the Commonwealth Government averaged about \$2million a year from 1971 to 1975 but, with the rescinding of the Act in 1974, remaining commitments dropped to about \$94,000 in 1976.

TABLE 21.5

R&D COSTS, OIL AND GAS INDUSTRY - ESTIMATED TYPICAL ANNUAL LEVEL OVER PERIOD 1967-1976

	<u>\$million (in 1976-77 dollar values)</u>
Exploratory drilling	83.72
Marine geology and seismic work	11.23
Other marine geophysics	0.19
Other (unassigned overheads)	5.57
TOTAL	100.71

21.3.16 Off-shore prospecting for minerals and commodities is a much smaller operation and is difficult to quantify. A conservative estimate would be that about 10% (\$90,000) of the total, non-hydrocarbon, R&D costs of the off-shore mining industry (\$900,000 in 1976) is absorbed in exploration (which may be considered to be analogous to research). It can be anticipated that exploration expenditure will increase as the need for mineral sands, and sand and gravel for construction, escalates due to shortages of land-based supplies.

21.3.17 Funds for both mining, and oil and gas exploration, at sea derive from the other operations of the companies involved. Ultimately these sources depend on success in finding and marketing resources, and in most cases these resources are located overseas. The notable exception is BHP, which operates widely in Australia but is now expanding into overseas areas. Since mid-1974 new Commonwealth subsidies have ceased, but at times during the last 20 years government subsidies have made a significant contribution to exploration costs. Further, many of the on-shore and off-shore programs of the BMR and some State survey projects contribute to the body of knowledge necessary for undertaking exploration and could be considered as a form of subsidy. Also, government agencies have approached exploration problems directly on occasion; for example, geophysical work by BMR on the off-shore plateaux of the northwest, BMR bottom sampling for mineral sands off central New South Wales, and seismic profiling for sub-bottom coal deposits by the New South Wales Geological Survey. Nevertheless, total government expenditures are equivalent to less than 5% of the private sector expenditure.

21.3.18 Table 21.1 shows total geosciences R&D at about \$2.7million, or about 12.5% of total marine sciences R&D. The universities do about 50% of this, the Commonwealth 25% and the States about 20%. Ocean geosciences (continental shelf and seabed studies) and basic estuarine and coastal studies each represent about 40% of marine geosciences R&D and environmental studies constitute the remainder.

21.3.19 Research in tertiary education institutions is supported by grants from the ARGC (1977 estimate, \$135,000), from the extractive industries (about \$150,000), and from co-operative ventures with government agencies (BMR, State geological surveys and other State agencies, and the Royal Australian Navy) (about \$200,000). These co-operative ventures include provision of ship time by the government agencies. Major current projects include: sedimentation studies in Western Port (University of Melbourne), in Exmouth Gulf (University of Western Australia), and along the Great Barrier Reef (University of Queensland); Southern Ocean manganese nodules (Monash University); seabed seismometers (Flinders University); and sea-floor magnetism off Fremantle (University of Sydney).

MANPOWER

21.3.20 In the petroleum industry much of the data collection, data reduction and interpretation are done by overseas-based geophysical contractors. According to the Australian Petroleum Exploration Association

Ltd, the petroleum industry employs about 12 bonafide marine geoscientists (e.g. hydrologists, and scientists studying recent marine sediments) as against 100 or more terrestrial geologists/geophysicists who happen to be working off-shore. In the universities, the number of scientists able to devote a significant proportion of their time to marine geology and geophysics is small, comprising about 40 marine geoscientists employed in some 16 centres. The BMR has about 20 full-time practising marine geoscientists.

21.3.21 There is some doubt that high-quality training in the marine geosciences can be given anywhere in Australia at present, because of the fragmented and dispersed nature of programs in the tertiary education institutions. Only two universities (Sydney and Flinders) possess the necessary staff with expertise to offer comprehensive training in the marine geosciences. Existing teaching programs do not utilise this potential fully because of small demands for such courses and the tendency to import trained personnel.

VESSELS

21.3.22 While estuarine and coastal geosciences seem to be served satisfactorily by small, university and State agency, vessels (except for shallow-water, drilling vessels), there is a real shortage of vessels for research on the continental shelf and in deeper waters. Estimated total ship time available for these purposes in 1977 was only about 40 days. This contrasts with the 188-280 days which the Consortium for Ocean Geosciences of the Australian Universities (COGS) estimates it could use for research and teaching in the first year of a continuing ship program in non-coastal areas. BMR estimates it could make use of a vessel for at least 180 days. Investigations on the continental shelf by State surveys might amount to another 60 days.

TRENDS

21.3.23 Sea-floor exploration is expected to increase, perhaps in the near future, in response to global shortages of energy and minerals. The slow expansion over the past few years probably reflects the world economic downturn. Estuarine and coastal investigations involving government agencies will probably continue to expand because of the increasing impact of man on the environment, the need for coastal structures, and because of mineral shortages. Responsibility for these tasks probably will rest with State and Commonwealth agencies (see Chapter 22, Coastal and Ocean Engineering). Apart from the general surveys undertaken by the BMR, relatively little deep-water work has been undertaken by Australian scientists in the Australian region. Lack of suitable vessels is one of the reasons for this. The establishment of a 200-mile economic zone will increase interest in this area.

DEFINITION OF AREA COVERED

21.4.1 Oceanography, the study of the oceans themselves, consists principally of components from the physical, chemical and biological sciences. The physical component is concerned especially with the interaction of the oceans and atmosphere which together operate as a single, strongly-coupled, dynamic system; with ocean tides and currents; the transport of materials in surface and deep waters; the deposition of sediments; and with wind and storm waves. It deals with temperature and salinity distribution and their role in ocean dynamics, and with dissolved gases, especially oxygen and carbon dioxide, and their role in geological and biological processes in the sea. Chemical oceanography is concerned with the chemical structure of ocean and shelf waters, with the productivity characteristics of water masses and with nutrient enrichment processes. It deals also with the pathways by which chemicals, including pollutants, are distributed within the oceans, absorbed, concentrated and transferred through the food webs; and with the chemical and geochemical processes of adsorption onto particles and incorporation into sediments. Biological oceanography deals with the description and inter-relationships of the biological communities which inhabit the oceans, both on the sea-bed and throughout the water itself. It is closely linked with physical and chemical studies, since it is the chemical conditions, such as the supply of nutrients, and transportation by the circulation of the water, which largely determine the abundance and composition of the communities.

21.4.2 Thus, researchers in oceanography are drawn from a very wide range of scientific disciplines. They include physicists, applied mathematicians, chemists (inorganic, organic and physical), and biologists (ranging from taxonomists to analysts of community structure).

21.4.3 Although there are no clear-cut boundaries, the field of oceanography embraces three fairly distinct regions; the open oceans, the waters over the continental shelves, and the coastal zone. The scientific emphasis, the support requirements, and the applications to practical problems, are different for each of these regions. For the open oceans, primary interest is in the large-scale circulation patterns and the mechanisms which drive them, and the most vital support need is for large, well-equipped research vessels. On the shelf, and still more in the coastal zone, the scientific problems are more complex and localised, involving interaction with the sea-bed and shoreline and with local meteorological conditions. Vessels, though still essential, may be smaller and more use can be made of fixed instrument arrays. Practical applications are much more numerous, including coastal engineering, pollution control and navigation.

POLICIES AND AGREEMENTS

21.4.4 Oceanography is not the subject of any specific Australian legislation or arrangements. International arrangements of relevance are Australia's membership of, and participation in the research programs of, the World Meteorological Organisation and the Intergovernmental Oceanographic Commission.

ORGANISATION

21.4.5 The two major research groups in oceanography are the Royal Australian Navy Research Laboratory (RANRL) and the CSIRO Division of Fisheries and Oceanography. The universities, as a group, do a considerable amount of oceanographic research, but the effort is very fragmented. Other groups in this field are the State conservation and environment agencies, the Bureau of Meteorology and the Australian Numerical Meteorology Research Centre.

21.4.6 RANRL is largely concerned with studies of the interaction between weapon systems and the marine environment, and its work is classified. The CSIRO Division of Fisheries and Oceanography employs the largest group of physical and chemical oceanographers in Australia (about 13 professional staff). These workers undertake research into large-scale, oceanic-water movements (concentrating at present on the East Australian Current), as well as some estuarine and coastal investigations. The Division formerly made significant use of Naval vessels but, as their availability has become more restricted in recent years, CSIRO has taken to chartering vessels for its work.

21.4.7 Although the universities as a whole carry out a significant amount of oceanography, the scientists and engineers specialising in physical oceanography and related problems are scattered throughout Australian universities. The largest groups, still not large enough to carry on sizeable projects, are located in the University of Western Australia (emphasis on estuaries), Monash University (tides, oceanic currents) and the University of New South Wales (waves).

21.4.8 University oceanographic research can be classified into three categories: observational, theoretical and experimental. Observational studies and monitoring programs by universities are practically non-existent except in estuaries, and experimental work is of limited scope. Most university oceanographers in Australia are involved in theoretical studies: some are trained as applied mathematicians and some are engineers. Chemical oceanographers specialising in ocean and sediment chemistry are represented by only a few academic scientists, mostly at Melbourne, James Cook and Sydney Universities.

21.4.9 The demands of State agencies for basic physical and chemical oceanography are usually satisfied by contracting with consultants or universities, and very few physical oceanographers are employed in State agencies. However, in oceanography related to environmental protection the States are quite active, though the work is less easily defined because of the diversity of the problems and the great differences between States in

the extent and nature of the organisational structure for handling them. This work is usually a part of a larger study including other fields such as environmental biology. Victoria has undertaken major investigations involving physical studies and the NSW Maritime Services Board also undertakes major hydraulic studies on proposed developments. Nearly all State oceanography is concerned with inshore situations, and not with physical and chemical oceanography of the open oceans, because it is in the inshore areas that the immediate environmental problems occur.

21.4.10 The Department of Defence operates a number of R&D establishments that undertake studies in the marine sciences and the most significant of these, as already mentioned, is RANRL. The other Defence establishments that are involved in marine studies are:

- . the RAN Hydrographic Service;
- . the Materials Research Laboratories; and
- . the Weapons Systems Research Laboratory.

The last two, together with RANRL, are components of the Defence Science and Technology Organisation.

21.4.11 The Hydrographic Service is responsible for the collation and dissemination of hydrographic and oceanographic data, and for the compilation, publication and supply of navigational information. The RAN Hydrographer (the head of the Hydrographic Service), is also responsible for the Australian Oceanographic Data Centre, which collects and stores oceanographic data (physical and chemical) for the waters adjacent to Australia. These activities are an important adjunct to research. The Materials Research Laboratories include in their Physical Chemistry Section, a Marine Environment Group which undertakes a range of biological and chemical studies related to marine fouling. The Weapons Systems Research Laboratory contains a Marine Physics Group, within which a small Oceanology Section undertakes studies of large- and meso-scale oceanic circulation in association with RANRL.

21.4.12 Also carrying out hydrographic work, but unconnected with the Department of Defence, is the Division of National Mapping of the Department of National Development, which is carrying out a program of bathymetric mapping of the continental shelf.

21.4.13 The CSIRO Division of Atmospheric Physics, the Bureau of Meteorology and the Australian Numerical Meteorology Research Centre (ANMRC) are all concerned with the physical and chemical processes that underlie and control weather and climate. They all, therefore, conduct research into those aspects of physical oceanography that deal with air-sea interactions.

FUNDING AND DESCRIPTION OF MAJOR R&D PROGRAMS

21.4.14 There are no specific schemes of research grants for oceanography, and individual, non-government scientists compete for ARGC and other such funds.

21.4.15 By far the biggest performer in the area of oceanographic R&D is the Defence Science and Technology Organisation, though the bulk of this is applied to weapon systems and is classified. Also, as with some other areas, it is difficult to separate research and service costs. Additionally, an unidentifiable proportion of RAN ship-time costs is allocated to various civilian scientists who occasionally obtain time on RAN vessels.

21.4.16 Taken together, civilian and defence oceanographic R&D represents about 33% of all marine R&D, with defence oceanography accounting for between 40 and 50% of this. However, because the results of most of this defence R&D are essentially unavailable to the civilian community, it is more useful to put the Defence R&D aside and therefore to consider civilian oceanography as constituting between 20 and 25% of total civilian marine sciences R&D. With this approach, the CSIRO work in the Division of Fisheries and Oceanography is the only major oceanography program in Australia because the university work is so fragmented. The current Australian research effort is spread fairly evenly across near-shore, off-shore, theoretical and experimental studies so that it is difficult to discern any particular pattern.

MANPOWER

21.4.17 There are few oceanographers relative to other marine scientists, and this reflects the difficulty of carrying out this type of research without suitable vessels. A large proportion of the oceanographers working in Australia have been trained overseas and any Australian student developing a career in oceanographic research would need to seek overseas experience at some stage. Although the concept of a critical size for effective research is not as relevant to universities as to independent research institutes, existing university groups are probably too small to pursue teaching programs effectively or to become involved in large-scale projects at sea.

VESSELS

21.4.18 The only oceanographic research vessel currently operating in Australia is the 45-metre 'Sprightly' chartered by CSIRO. However, this situation may improve to some extent in the foreseeable future (see 21.1.26).

TRENDS

21.4.19 As the exploitation of off-shore resources increases and the need for better weather forecasting and protection of the marine environment become more pressing, the demand for oceanographic research will

increase. It is understood that the CSIRO Executive has arranged for an independent review of its programs in oceanography, but, in the national context, Australia's capability and effort in oceanography R&D is improving only slowly. The foundations for the development of physical and chemical oceanography are narrow, but work with an engineering or estuarine orientation probably has a broad enough base to allow reasonably rapid increases if funds became available. As a discipline, physical oceanography of the continental shelf is less advanced and receives less attention in international co-operative projects than does deep-water oceanography.

21.5 MARINE ENVIRONMENTAL STUDIES

DEFINITION OF AREA COVERED

21.5.1 Marine environmental studies are here defined as those projects which apply science and technology to the correction or avoidance of undesirable changes to our marine environment. Consequently, most marine environmental studies are applied research, though those aimed at elucidating the processes involved in the environment are basic research. Marine environmental studies cover such things as assessment of the baseline situation, modelling of the pollution process and bioassay of marine organisms.

21.5.2 The general topic of environmental R&D is dealt with in Chapter 36 of this Report, so the discussion here is aimed simply at putting marine environmental studies into the context of the marine sciences generally.

POLICIES AND AGREEMENTS

21.5.3 At the national level, the Department of Environment, Housing and Community Development (EHCD), as part of its responsibilities, advises the Commonwealth Government on policy for the protection of the marine environment. It also develops mechanisms for this protection and devises and implements Commonwealth legislation to enable the Commonwealth to fulfil its obligations in this regard. EHCD has, as one of its functions, the promotion of research relevant to the protection of the marine environment.

21.5.4 The development and implementation of national policy is based primarily on Commonwealth/State co-operation and is achieved through the Australian Environment Council (AEC), which deals with environmental matters, including marine matters, of concern to both the Commonwealth and the States, and through the Council of Nature Conservation Ministers. Like the Australian Fisheries Council (see 21.2.8), the AEC consists of the appropriate Ministers of the Commonwealth and State Governments, and is supported by a Standing Committee of senior officials. Part of its function

is to deal with matters related to the protection of the marine environment and the question of marine pollution is a standing item on its agenda. Much of its work in this field is done in association with the Australian Fisheries Council through the Joint Technical Working Group on Marine Pollution. The Commonwealth's activities are related to international obligations arising from Australia's participation in such organisations as the Organisation for Economic Co-operation and Development (OECD), the United Nations Environment Program (UNEP) and the Intergovernmental Maritime Consultative Organisation (IMCO). The Department (EHCD) is involved in Australian participation in the UN Conference on the Law of the Sea, the International Oceanographic Commission, the UN Environment Program and the IMCO London Dumping Convention 1972 (see 21.1.6).

21.5.5 Neither the AEC nor the Commonwealth Government has developed explicit policy objectives for the marine area. However, the AEC's Research and Studies Advisory Committee has identified marine pollution R&D as an area of high priority, and international factors, such as Australia's planned ratification of the London Dumping Convention and the outcome of the Law of the Sea Conference, may well provide the necessary objectives. The Commonwealth has introduced the Environment Protection (Impact of Proposals) Act 1974, administered by the Department of EHCD, to enable environmental protection to be effected by assessment of proposed developments before their implementation.

21.5.6 Policy arrangements in the States vary considerably and tend to reflect the particular circumstances and history of each State. A number of co-ordinating committees exist in the various States for the purpose of promoting co-operation in the environmental field. Some of these, such as the Gladstone Powerhouse Committee of Queensland and the Port Phillip Bay Strategy Committee in Victoria, co-ordinate activities affecting major development problems where several agencies are involved. Other committees, such as the Clean Waters Advisory Committee of New South Wales and the Water Quality Data Collection Committee in Victoria, are more directly concerned with the control of water pollution. The value of such committees in promoting co-operation in environmental projects affecting several agencies is now generally recognised.

21.5.7 From time to time the Australian Marine Sciences Association puts forward views on various marine science topics including the scientific aspects of environment protection.

ORGANISATION

21.5.8 The Department of EHCD is not engaged directly in marine R&D, but is involved in marine matters in several areas. Its activities include: identification of national research and monitoring needs as they affect the

marine environment; development of a national data-bank of marine environmental parameters; and the accumulation of environmental impact statements concerning off-shore activities. The development of marine national parks is undertaken by the Great Barrier Reef Marine Park Authority and the Australian National Parks and Wildlife Service, both of which advise the Minister for Environment, Housing and Community Development. The CSIRO Divisions of Applied Geomechanics, Land Use Research and Land Resources Management all have a minor interest in marine environment studies. AIMS has a program on tropical marine pollution and is concentrating at present on the distribution of chloro-organic compounds and on detoxification processes for heavy metals.

21.5.9 The environmental protection agencies in most States undertake some scientific studies in the marine field. These are generally directed towards either the possible effects of proposed harbours and other coastal development or the environmental effects of existing or proposed outfalls of either domestic sewage or industrial wastes. In Victoria and Western Australia, the Ministry for Conservation and the Department of Environment and Conservation respectively are devoting large resources to continuing studies of this kind. In the other States, however, such activities are relatively minor. In Victoria, both the Melbourne and Metropolitan Board of Works, through its Environmental Studies Group, and the Ports and Harbour Division of the Public Works Department are undertaking environmental studies relating to proposed or possible future development. The Melbourne Harbour Trust also provides financial support for other organisations involved in this work. In New South Wales the Maritime Services Board is undertaking similar studies. Most State fisheries groups also carry out some R&D relating to environmental protection, primarily because marine living resources are dependent on the quality of their environment, and also because, at least initially, they were the only agencies capable of conducting marine biological research.

21.5.10 The marine, scientific, consulting industry is not well developed in Australia and there would seem to be only about 15 companies or individuals involved. Design of outfalls and other marine structures and the assessment of their environmental impact is one of their activities. Some marine consulting and contract research is undertaken by a number of universities and a few colleges of advanced education. Most of this is concerned with the environmental impact of proposed or existing development schemes and is undertaken on behalf of government agencies and statutory bodies.

21.5.11 While most tertiary education institutions have taken up environmental teaching and research in response to society's concern, only two universities (the University of Melbourne and the Australian National University) have major environmental studies groups. In most universities, therefore, marine environmental R&D is taken up within biology, geology or chemistry schools, or sometimes through marine studies centres where these exist.

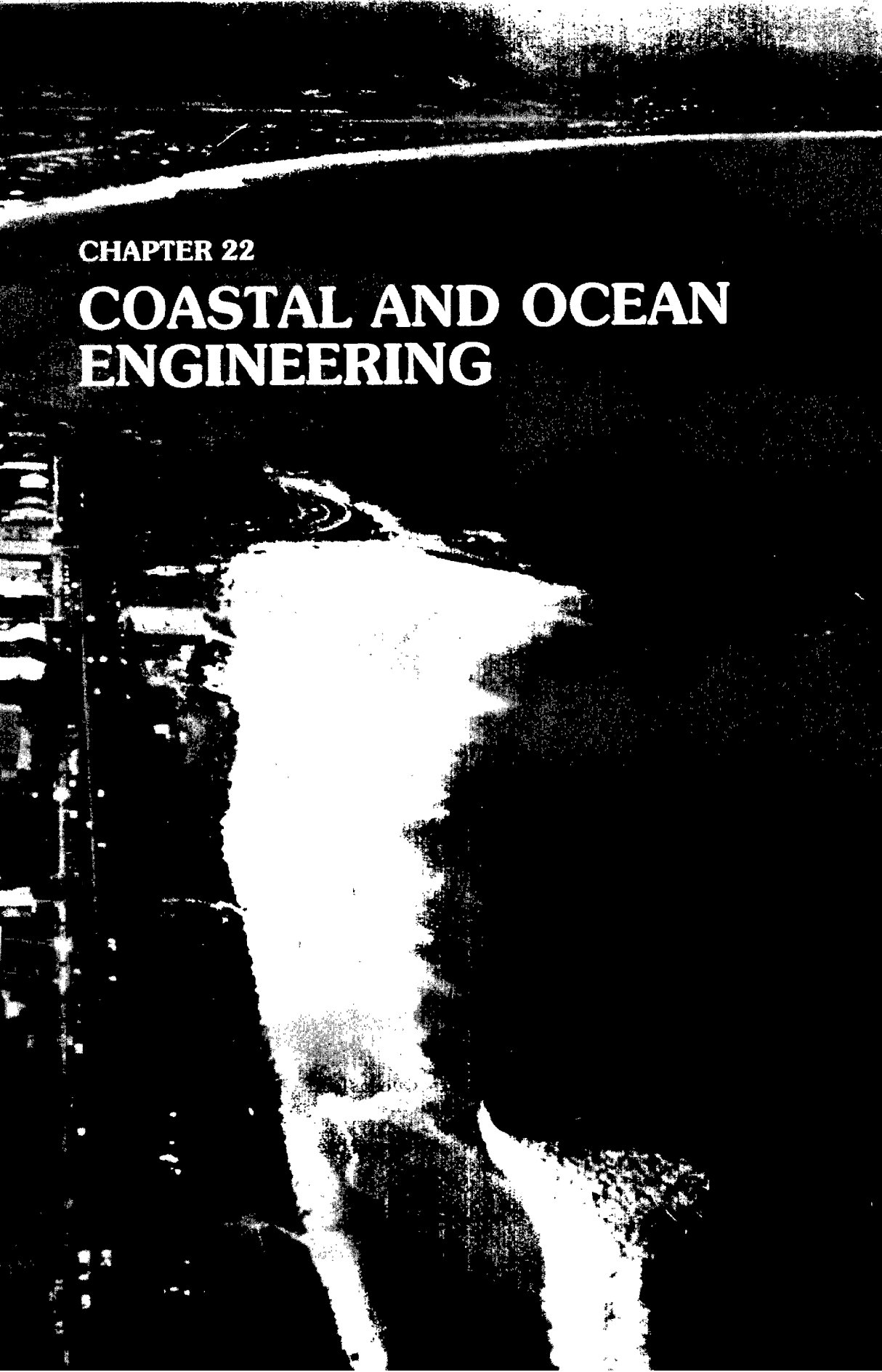
FUNDING AND DESCRIPTION MAJOR R&D PROGRAMS

21.5.12 The States are the biggest performers of marine environmental R&D (over 60%) and essentially all of this (over 95%) is internally financed. The universities are the next biggest group (nearly 25%) and nearly all their research is financed from general university funds. The Commonwealth carries out between 10 and 15% of marine environmental R&D.

21.5.13 Chemical oceanography (pollution and heavy metal studies) and physical oceanography (meteorology), in the ratio of 10:1, together represent about 50% of the environmentally oriented R&D; ecological studies almost 40%; and geosciences R&D the remainder.

NOTES AND REFERENCES

1. 'Marine Science in Australia', Report of the Interim Council of the Australian Institute of Marine Science, 1971, 52 pp.
2. 'Financing Rural Research', Industries Assistance Commission Report, 1976, 282 pp.
3. 'Draft Report on Harvesting and Processing of Fish, Crustaceans and Molluscs', Industries Assistance Commission, 1978, 141 pp.
4. 'The 200 mile Australian Fishing Zone', A report of the working group established by the Australian Fisheries Council, 1977, 76 pp.
5. Royal Commissions Into Exploratory and Production Drilling for Petroleum In The Area of the Great Barrier Reef, The Parliament of the Commonwealth of Australia; Parliamentary Paper Nos 38 and 39, 1975, 1052 pp.



CHAPTER 22

COASTAL AND OCEAN ENGINEERING

Photograph: A groin at Kirra in Queensland. Beach sand has accumulated to the south of the groin, but this has been at the expense of the coastline to the north.
(Photograph courtesy Commonwealth Department of Construction).

CHAPTER 22

COASTAL AND OCEAN ENGINEERING

22.1 INTRODUCTION

22.1.1 Coastal and ocean engineering cover a very wide range of activities which extend from the shore (coast) out into deep water (ocean). The objectives include the management of the coastline so that life and property will be protected (particularly against cyclonic storm surge), beaches will be maintained and improved, and facilities for pleasure craft will be provided to contribute to the increasingly important leisure industries. The community's economic well-being depends on exploiting physical resources such as natural gas, oil, and sea-bed minerals; coastal and ocean engineering are important if exploitation is to have a minimum of undesirable side effects. Coastal engineers are responsible for constructing and operating efficient ports (inshore and off-shore) and navigational aids so that the communities' exports and imports can move smoothly. The coastal engineer uses the natural dispersion and dissipation characteristics of the coastal margin for the effective functioning of sewage and drainage outfalls. His control over the ocean margins has important relations to fishing and other essential activities such as the enforcement of quarantine regulations and the prevention of smuggling. Finally, the objectives of coastal and ocean engineering must fulfil national and international obligations in fields such as marine pollution and the preservation of marine flora and fauna.

22.1.2 These objectives can be met only if a very wide range of research activities, covering varied subject matter, is undertaken. Fundamental research is essential, especially to determine the physical processes involved in coastal and ocean engineering: wave mechanics and forces; tidal theory and propagation; storm surge development and propagation; sediment transport on beach and seabed and in estuaries; effects of density currents on sedimentation and water quality; and physical studies of the deep seabed are all essential. Development of fundamental research is necessary for general types of engineering projects; it will involve studies of the stability of tidal inlets, wave forces on various engineering structure profiles, harbour configurations which reduce waves and avoid resonance, scouring around footings of structures, dredging methods and others. Examples of off-shore development activities are: determinations of structure types and their foundations; development of tools such as submersibles; and the development of physical ocean resources to provide useful energy from wind, currents, waves and tides. Project investigations involve the application of fundamental R&D to design, and this stage of the engineering project often reveals gaps in fundamental R&D. Investigations often take the form of model tests, either physical or mathematical, for a given component of design. Finally, all these stages of R&D are an essential component of the total engineering process which includes the design, construction and management of the whole project.

22.1.3 The fulfillment of the objectives of coastal and ocean engineering also requires: adequate educational opportunities; arrangements for collecting, classifying and disseminating data; and engineering capability in design and construction. Each of these elements is interdependent.

22.2 POLICIES AND AGREEMENTS

22.2.1 There are no overall policies, guidelines, national goals or national needs, defined at governmental level or elsewhere, for R&D in coastal and ocean engineering.

22.2.2 Over the last five years the Institution of Engineers, Australia has attempted to compensate for the lack of a policy-making body at the national level by the formation of a National Committee on Coastal and Ocean Engineering. This group includes representatives of most of the bodies involved in the field, but, by its nature, is purely advisory.

22.2.3 There are two main fora used for the important interchange of ideas between Australian engineers and scientists in coastal and ocean engineering and their counterparts in other countries. These are the Australian Coastal and Ocean Engineering conferences and the International Coastal Engineering conferences. These are both held every two years, the Australian conferences being held in years alternate with the international conferences.

22.3 ORGANISATION OF R&D

22.3.1 About 40 establishments were contacted regarding their R&D role in coastal and ocean engineering; those responding, as being active in the area are listed below.

Universities and colleges: James Cook University of North Queensland; University of Queensland; University of New South Wales; Monash University; University of Melbourne; Deakin University; Flinders University of South Australia; University of Adelaide; University of Western Australia; and Caulfield Institute of Technology, Victoria.

Commonwealth government departments: Department of Construction (Maritime Works Branch); Department of Defence (RAN Hydrographer and RAN Research Laboratory); Department of Science (Bureau of Meteorology); and Department of Transport.

- State government departments: Department of Harbours and Marine, Queensland; Department of Public Works, NSW; Public Works Department, Victoria; Public Works Department, WA.

- Government authorities: Beach Protection Authority, Queensland; Maritime Services Board of NSW; Port Phillip Authority, Victoria; Soil Conservation Authority, Victoria; Melbourne Harbour Trust Commissioners, Victoria; Coast Protection Board, SA; CSIRO Division of Fisheries and Oceanography, Division of Mechanical Engineering, Division of Applied Geomechanics; Australian Atomic Energy Commission.

- Industry: Esso Australia Ltd; Woodside Petroleum Development Pty Ltd.

22.3.2 Most of the fundamental R&D is undertaken in universities with smaller, but significant, programs within the Department of Science and the CSIRO. In other establishments the majority of the work is oriented towards project investigations with up to 20% of the effort being devoted to fundamental R&D. There are no formal, or even regular, provisions for interaction between the different establishments.

22.3.3 In contrast with England with its Hydraulics Research Laboratory at Wallingford, Holland with the Delft Hydraulic Laboratories, and Canada with three centres having significant involvement in the field, Australia has no major investigational facilities.

22.3.4 Although several universities have active, if limited, research programs in progress, there is no institution offering a full-time, formal course in coastal and ocean engineering, although several institutions do offer specific units. Expertise is spread thinly through the universities with a maximum of two lecturers knowledgeable in coastal or ocean engineering at any one institute. Most experienced coastal or ocean engineers in Australia have obtained their training or expertise overseas.

22.3.5 The National Committee on Coastal and Ocean Engineering of the Institution of Engineers, Australia, which is the only authoritative group in the field, has stated that there is a demonstrable need for a National Centre to act as a co-ordinating body for research, investigation and development in this branch of engineering. It has been suggested that the functions of the Centre would be to provide guidelines and co-ordination for R&D; to co-ordinate and store data in an accessible manner; to provide advice to government; to be a centre of expertise and information; to provide support to teaching centres in coastal and ocean engineering; and to provide the functions of a Tidal Institute.

22.3.6 It has also been proposed that there is a need for the establishment of a training centre of some kind or for support to an existing institution, perhaps one associated with the National Centre for coastal and ocean engineering; this has been referred to in Chapter 7 of Volume 1A of this Report. This proposal would be one of the matters comprehended by the Ministerial discussions recommended in Chapter 7 of Volume 1A.

22.4 FUNDING

22.4.1 There are basically three types of funding available:

- funding from ARGC and general university research funds to university research units; these funds are mainly used to support fundamental research and, excluding salaries, amount to less than \$100,000 per annum although they support 20 to 30 man-years of research;
- funding by governments and industry to universities or consultants for R&D for specific projects; and
- funding for project investigations by governments and the oil industry.

Between \$3million and \$5million is spent yearly in Australia on the last two categories.

22.4.2 In addition, it has been found necessary to use overseas consultants (particularly Dutch, English and American) because of lack of Australian expertise and facilities in certain areas. It is not possible to estimate exactly what funds are used on overseas consultants but the average yearly figure would exceed \$100,000. It can be anticipated that this will be very much greater when the off-shore oil and gas industry develops.

22.5 CONDUCT OF R&D

DESCRIPTION OF ESTABLISHMENTS

Universities

22.5.1 R&D is usually initiated and controlled by individual staff members of Civil Engineering Departments, although some indirect control may be exerted by the university committee that allocates research funds. Planning and review is then mostly done at the discretion of the individual researcher. Exceptions occur at the University of NSW and at other universities where R&D is controlled centrally.

22.5.2 At the University of NSW all R&D on coastal and ocean engineering is done by the Water Research Laboratory where the Officer-in-Charge co-ordinates and reviews all studies. This laboratory conducts the largest volume of experimental R&D and is also active, as are Monash and James Cook Universities, in the theoretical and numerical

modelling aspects of coastal engineering research. The R&D effort of these three universities is reinforced by consulting contracts from government and industry.

22.5.3 The University of Western Australia, University of Queensland, and University of Adelaide have a research effort that is quite intensive, in terms of manpower, but the scale of the research attempted is limited by the funds available.

22.5.4 Flinders University of South Australia has an effort more closely associated with oceanography than with engineering and the research studies carried out at the University of Melbourne, Deakin University and Caulfield Institute of Technology are limited to one to two man-years per year supported by minimal funds.

Commonwealth government departments

22.5.5 Significant efforts in coastal and ocean engineering R&D are undertaken by the following departments:

- . Construction;
- . Science (Bureau of Meteorology);
- . Defence (Royal Australian Navy - RAN); and
- . Transport,

Within each of these Departments there is a unit involved with coastal and ocean engineering or related matters, although only the Maritime Works Branch of the Department of Construction contains coastal engineers as such.

22.5.6 In the Department of Construction, coastal and ocean engineering is handled by the Maritime Works Branch. Research, development, and investigation programs are an essential part of the project work and, over the last five years, the involvement of the 15 engineers in the Branch in coastal engineering projects has varied from 'almost continuous' to 'spasmodic'. Organisation of R&D is under the control of project officers with reviews by the Chief Engineer (Maritime Works).

22.5.7 The Bureau of Meteorology (Department of Science) is concerned with research into those aspects of marine meteorology, physical oceanography, and coastal engineering that are important to the provision of meteorological services as specified in the Meteorology Act 1955-73. Most of its R&D effort in coastal and ocean engineering is undertaken by the two professional staff in the Oceanography Unit of the Physical Research Section of the Bureau's R&D Branch.

22.5.8 The Department of Defence has two groups working in areas related to coastal and ocean engineering, namely the RAN Hydrographic Service and the RAN Research Laboratory, Sydney. At the RAN Research

Laboratory there is an engineering group of 18 with an annual expenditure, including overheads, of \$500,000. A large proportion of these resources is devoted to physical oceanography and is therefore included in Chapter 21 on the marine sciences, as is a reference to the work of the RAN Hydrographic Service (see 21.4.11); the latter will be mentioned later in connection with tidal matters (see 22.5.44).

22.5.9 In the Department of Transport, the Navigational Aids Branch is responsible for any involvement in coastal and ocean engineering R&D. Over the last 10 years the Department has spent about \$500,000 on contract measurement of tides and currents in Torres Strait.

State government departments

22.5.10 In New South Wales, Victoria, and Western Australia, Public Works departments have strong involvement in coastal engineering through the formation of separate sections within the departments. Because each of these sections is part of a works organisation, any R&D activities are apt to be a by-product of investigations for specific marine works. Consequently funding estimates are approximate only and usually include investigating costs for coastal engineering projects.

22.5.11 In New South Wales the Coastal Engineering Branch of the Department has been set up to establish and maintain expertise related to the coastal environment, so as to be able to provide advice to all who need it. There is a staff of 75 engineers and technical officers; funds are usually derived from State revenue. In the area of investigation and data collection about 11 engineers and technical officers are involved; the average annual budget is \$1million excluding salaries and overheads. The aims of the Branch include:

- improvement of the general understanding of shore processes throughout the State, by analysis of past records, by monitoring of physical parameters, and by examination of geomorphological indicators; and
- investigation and design of shore protection works and harbour works which are effective and economic in the local context.

22.5.12 In Victoria, coastal engineering work is carried out in the Investigation Section of the Ports and Harbours Division whose primary function is to find solutions for particular coastal engineering problems. The section has an establishment of five engineers, four technical officers, and trade and administrative support funded from State votes. Projects are funded as separate items and are subject to yearly allocation and review. The average annual budget excluding salaries and overheads, is \$200,000-\$300,000, of which some 10-20% is devoted to fundamental R&D.

22.5.13 In Western Australia the organisational structure is similar to that in Victoria and consists of a Coastal Investigations Section, which is part of the Harbours and Rivers Branch of the Public Works Department. The section staff consists of four engineers and three to four technical

officers who spend up to 20% of their time on fundamental R&D and the remainder on investigations (applied R&D).

22.5.14 In Queensland the State government department involved is the Department of Harbours and Marine; coastal engineering work is done within the Harbours Works Branch which, however, does virtually no R&D itself. This work is usually contracted out to universities.

22.5.15 In South Australia the relevant authority is the Department of Marine and Harbours; work in coastal engineering is irregular so that there is no set organisation for doing such work.

22.5.16 In Tasmania responsibility for coastal works mainly resides with individual harbour boards and it is difficult to obtain a comprehensive picture. The scale of activity in Tasmania is small.

Government authorities

22.5.17 The CSIRO Divisions with an interest in the field are the Division of Fisheries and Oceanography, and the Division of Mechanical Engineering. Most of the activities of the former are covered in Chapter 21 on the Marine Sciences, although many of these activities are linked with the sciences related to coastal engineering. The Mechanical Engineering and Applied Geomechanics Divisions have only recently taken an interest in ocean engineering and, although their activities are at present limited it is intended to expand the effort.

22.5.18 The Isotope Division of the Australian Atomic Energy Commission (AAEC) is working on a number of topics in this field. Much of the work is a product of the consulting service offered by the AAEC, although some basic R&D is being undertaken. The effort is mainly in studies of silt and sand movement, water flow and effluent dispersal.

22.5.19 The Beach Protection Authority, Queensland, is primarily an investigatory body. The Authority has an Advisory Board and obtains its support (10 professionals and 12 technical and administrative staff) from the Department of Harbours and Marine. Fundamental R&D has an average annual budget of \$70,000 while the remaining budget, amounting to some \$800,000, mostly goes to the collection and analysis of coastal engineering data. These figures include overheads and salaries of the 22 support staff. The Authority is in the forefront of coastal zone management in Australia and carries out work on beach profiling, sand movement, and wave data collection and analysis.

22.5.20 The Maritime Services Board of NSW conducts all its coastal engineering R&D at the Hydraulics Research Building where the staff consists of three engineers and four technical officers. Policy is formulated by the Principal Planning Engineer. Funding is from the Board's revenue and amounts to approximately \$200,000 annually including salaries. Fundamental R&D accounts for about 25% of the research effort.

22.5.21 The Port Phillip Authority, Victoria, advises the Victorian Government on the administration of the Port Phillip area for the full benefit of the public; it has an R&D team of four professionals augmented by technical assistants and labour as required. It has an average annual R&D budget of about \$100,000 but a large proportion is spent on land use and similar studies not directly related to coastal engineering.

22.5.22 The Soil Conservation Authority, Victoria, has a continuing research program on the stabilisation of coastal dunes in Victoria with a full-time staff of one senior research officer and a works assistant.

22.5.23 The duties of the Coast Protection Board, South Australia include protection, restoration and development of the coast. The Board has financed a small amount of fundamental research at tertiary institutions and undertakes collection of long-term data in the form of beach profiles. The staff of 13 (5 professional, 5 technical, 3 clerical) is provided through the SA Department of the Environment.

Industrial organisations

22.5.24 In coastal and ocean engineering the only significant R&D outside tertiary education and governmental institutions, is that conducted by oil companies involved in off-shore developments. Esso Australia Ltd and Woodside Petroleum Development Pty Ltd are involved but much of the R&D is done overseas.

22.5.25 Esso Australia Ltd is an affiliate of the Exxon Corporation; most of Esso's R&D is done abroad through research establishments operated by Exxon. The work done within Australia is at present limited to the collection of such field data as is required for the R&D effort.

22.5.26 Woodside Petroleum Development Pty Ltd (WPD), as the operator for the North West Shelf Joint Venture, is responsible for exploration and development of hydrocarbons within the leases. WPD is required to identify the areas where R&D is needed to effect proper engineering design, and to have the necessary work carried out. Both WPD staff and consultants are used on R&D depending on the quantity and type of work involved. Staff numbers vary and are difficult to quantify, but over the last five years an average of \$300,000 per annum, including salaries and overheads, has been expended on R&D and deep-water investigations on the north-west coast of Australia.

DESCRIPTION OF MAJOR PROGRAMS

22.5.27 In any system of classification of R&D activities in the area of coastal and ocean engineering there will be considerable overlaps because of the spread of activities across the coastal systems. For the present purpose, R&D programs have been classified under nine headings.

Coastal management

22.5.28 This is a broad classification covering 20-30% of the total R&D resources (including special investigations). Most of the R&D programs are part of multi-disciplinary studies. There are seven separate programs each with annual expenditure, for coastal engineering, of between \$50,000 and \$200,000, including salaries, that have operated for at least two years. Some of these programs will be completed in 1978.

22.5.29 The programs are:

- . a study for the Melbourne Harbour Trust by Melbourne and Monash Universities to provide baseline data on the physical, chemical and biological conditions of the waters, bed and shoreline of Port Phillip Bay in the area influenced by Trust activities. This is a two-year program due for completion in late 1978;
- . other independent coastal studies in Port Phillip Bay. The first of these is by the Public Works Department, Victoria, which is measuring and studying winds, waves, tides, currents, sedimentology, geomorphology, bathymetry and sediment transport. This is to obtain an understanding of the region and to provide qualified design criteria and base data for more specific investigations. This study is 75% complete and has about one year to run;
- . the second independent study is by the Port Phillip Authority which is more concerned with the area above high-water mark. The study just completed was undertaken to develop a balanced approach to the use of the coastal resource that considers both priorities for, and compatibility of, use and preservation;
- . a study by the Beach Protection Authority of Queensland aimed at improving methods of re-establishing, stabilising and managing damaged coastal sand dunes by using re-vegetation and sand drift fences. This is a continuing program whose results will have wide application along the Queensland tropical coast;
- . the investigation of coastal behaviour in several Queensland shires by the Beach Protection Authority. The program comprises wave recording, surveying off-shore seabed profiles, current measurements, sand sampling, aerial photography, field inspections and daily measurements of the sea and beach conditions by volunteer observers living adjacent to the beaches. This information helps the Authority to provide advice on beach erosion problems and to suggest means of avoiding future problems. This is also a continuing program;
- . for each coastal district in SA a management plan is to be produced by the Coast Protection Board, indicating areas to be preserved and areas that may be developed and identifying

problems. Fields covered in the studies include land-use mapping, flora, fauna and geological assessment, and existing and potential uses of the area. Current, or likely, erosion problems are also assessed. Once a management plan is declared, controls for the prevention of inappropriate use can be applied and expenditure authorised.

22.5.30 A study that is now virtually complete was conducted by the Commonwealth Department of Construction with some assistance by other bodies, at Cockburn Sound, Western Australia. An environmental baseline of beach morphology, currents, waves and the ecosystem as a whole was established to assist in the design of the works for, and to monitor any changes caused by, the construction of the Naval Base and canals. The study was one of collection and analysis of field data, augmented at a later stage by numerical modelling.

Off-shore structures

22.5.31 The major R&D effort on off-shore structures is by Woodside Petroleum Development Pty Ltd, which spent \$600,000 from 1972 to 1974 investigating the soil mechanics of off-shore sediments. The sediments of the North West Shelf are low-density calcareous silts and sands which are granular in texture but behave like soft clays. Normal procedures of soil mechanics do not accurately predict the behaviour of foundation piles in these materials. Further studies are planned using a specially-equipped ship for foundation investigations. The total program cost since 1972 is \$3.8million of which approximately \$1.2million is for R&D. Other R&D work for off-shore oil development is primarily conducted overseas due to shortage of facilities in Australia and is not included here.

Waves

22.5.32 There are at least eight organisations involved in the collection and analysis of wave data, each with an annual expenditure of between \$10,000 and \$20,000, including salaries and overheads. These yearly budgets do not include the cost of equipment for data collection.

22.5.33 The R&D effort has concentrated on: using wave measurements to define wave climates; improving wave refraction calculations; developing methods of analysis, equipment and programs; improving methods of description of storm durations and return intervals; and developing sea-state/wave-forecasting systems, including cyclone-generated wave systems.

22.5.34 The organisations involved at the expenditure level indicated are James Cook University of North Queensland; Department of Public Works, NSW; Maritime Services Board of NSW; Department of Public Works, Victoria; Public Works Department, WA; Commonwealth Department of Construction; Bureau of Meteorology (Department of Science); Beach Protection Authority, Queensland; and Woodside Petroleum Development Pty Ltd. Different methods of analysis are used because of the differences between available wave recording and analysing equipment. There is also

laboratory research on monochromatic waves at Queensland and Monash Universities and at the Universities of NSW and of WA.

Estuarine, inlet and lake processes

22.5.35 The Public Works Department of NSW is by far the most active group with an annual expenditure of about \$200,000, excluding salaries and overheads, on studies which include:

- . the development of a predictive model of estuarine processes for use in promulgating river and nearby shoreline management policies for the Tweed and Georges Rivers and for Port Stevens; and
- . the development of mathematical techniques to examine effects of various proposals to increase current circulation within the Tuggerah Lakes.

22.5.36 At various times over the past five years, Monash, Queensland and James Cook Universities have worked independently on the development of numerical models for flow and pollutant transport in estuarine and bay systems. The study at Monash, costing about \$30,000 per annum (excluding professional salaries), over four years, is complete while the other two smaller-scale studies are continuing.

22.5.37 Another program at Monash is the measurement of large-scale turbulence in fast-flowing tidal inlets in order to determine dispersion and mixing. This is a continuing program with an annual budget of about \$15,000, excluding salaries.

Beach processes

22.5.38 The beach processes classification overlaps that of coastal management, the main distinction being that most coastal management studies are multi-disciplinary.

22.5.39 The Public Works Department of NSW features strongly in this category with annual expenses of the order of \$150,000, excluding professional salaries and overheads. This covers in-house studies of the behaviour of beach fills with artificial nourishment; the development of a predictive mathematical model for shoreline alignment; and the study of sand transport by waves and currents. About half of these studies are contracted out to the Water Research Laboratory of the University of NSW.

22.5.40 The Public Works Department, WA is conducting an investigation of the age, source and transport mechanism of shore sands at Geographe Bay; water level oscillations are also being studied.

22.5.41 Continuing laboratory studies of beach processes, supplemented by some field observations, have been conducted for at least five years at the Universities of Queensland and Western Australia. These are fundamental research projects on the effects of foreshore structures on currents, waves and sediment transport.

Currents, tides and storm surge levels.

22.5.42 Much of the R&D effort in these matters has been covered in Chapter 21 on the Marine Sciences. From an engineering viewpoint the R&D activity is as follows:

Esso Australia Ltd, and Woodside Petroleum Development Pty Ltd require information on currents for the design of their off-shore drilling and production rigs. Woodside spent \$500,000 from 1972 to 1975 obtaining water current measurements on the North West Shelf; these measurements were the first of their kind in the area. Esso is measuring currents and waves continuously for at least a year at two fixed locations in Bass Strait, and will make the data available to the Bureau of Meteorology and to the RAN Research Laboratory;

the Beach Protection Authority of Queensland has a considerable interest in water-level measurements, particularly in relation to cyclone surges, and has six water-level recorders installed for monitoring storm surges associated with cyclones along the Queensland coast. The long-term aim of the data collection is the accurate prediction of storm surges accompanying cyclones of known characteristics;

the Public Works Department of NSW is planning similar storm water-level studies (non-cyclonic). The estimated overall cost is \$200,000, excluding salaries;

the Commonwealth Department of Construction has for some time financed an intensive program of research into cyclone-produced storm surges, with numerical modelling for Darwin, Brisbane, and Townsville. The program is being continued, as required, for other sites where the Commonwealth has a responsibility;

the Bureau of Meteorology of the Commonwealth Department of Science has a continuing interest in cyclones and storm surges and is developing forecasting procedures for storm surges in the Australian tropics. In the past it has provided estimates of long-term statistics for extreme ocean waves, storm surges and wind gusts generated by tropical cyclones in a form suitable for engineering design purposes;

the James Cook University of North Queensland has, over the last three years, developed and evaluated a numerical model describing storm surges due to tropical cyclones that is applicable to ten coastal sites in Queensland. The approximate cost was \$75,000, excluding salaries.

22.5.43 At a more general level, tidal matters in Australian waters are handled mainly by port operating authorities, the RAN Hydrographic Service and Flinders University of SA. Port operating authorities collect tidal recordings which are then analysed either by the Institute of

Oceanographic Sciences, UK, or by Flinders University of SA so that predictions can be made. The main role of the RAN Hydrographic Service is to collate and present tidal and bathymetric information to the public.

Coastal structures

22.5.44 R&D on coastal structures, and their effects on the shoreline, is currently receiving significant attention at four centres each of which has spent between \$20,000 and \$50,000 per annum, excluding salaries and overheads, in recent years.

22.5.45 The Department of Public Works, NSW, and the Public Works Department, Victoria, are investigating the effect of coastal structures on the shoreline at Narooma and St Kilda respectively. At Narooma the study is being conducted in the field by monitoring changes as the structure is being built; at St Kilda the basis of the study is a scaled hydraulic model from which predictions will be made. The investigations mentioned in 22.5.41 are also relevant here.

22.5.46 The University of NSW has a continuous program on the development and design aspects of breakwaters and revetments, including an investigation of the most relevant design parameters. At the James Cook University of North Queensland the research effort over the last three years has been directed to an experimental investigation of forces on cylindrical piles from waves and currents.

Ship motions

22.5.47 There is very little R&D done in Australia on ship motion. At present the only such study is being conducted by the Maritime Services Board of NSW which is investigating the under-keel clearance requirements of large crude-ore carriers when entering a harbour under the influence of waves and currents. The study is being carried out at model scale.

Harbours

22.5.48 Several of the prior classifications impinge upon harbour programs, but in addition there is a group of miscellaneous programs dealing with problems such as the corrosion of steel and reinforced concrete used in harbour construction and the attack of marine organisms on timber used similarly.

AREAS REQUIRING R&D

Collection of data

22.6.1 The first problem arising in any coastal or ocean engineering project is the need for basic data of wind, tide, wave and current records. There are large areas along the coastline and off-shore where

this information, which will be needed for the development of Australia's coastal and offshore resources, does not exist. There is also a lack of fundamental data for engineering design and often when data does exist it is difficult to retrieve because of the lack of an adequate archival system. Most of the data that does exist has been collected, often over a rather short time-span, in connection with particular projects. The port authorities have recently pressed for the provision of a Tidal Institute to co-ordinate tide readings, analyses and predictions, and it would probably be feasible and economical for this institute to be incorporated in the Centre suggested in 22.3.5-6.

Beach processes

22.6.2 Some research is being conducted at nearly every university but the funds available are small. For useful progress to be made, as required for the proper management of the foreshore, this area would require a considerable expansion.

Breakwaters

22.6.3 Breakwater construction is an expensive and necessary part of many coastal engineering works and it is important to improve methods and designs so as to achieve maximum economies. Research programs, at the Universities of NSW and of WA, that could result in considerable savings in construction costs in the future, are being held up because of the small funds available.

Cyclone Surge and associated phenomena

22.6.4 Over the last four years there has been a considerable effort in this area but most of these programs are complete or slowing down. If allowances for cyclone surges are to be incorporated in planning, these research activities should be increased. Such information will also be needed for the National Disaster Insurance Scheme if it progresses.

Floating structures and ship dynamics

22.6.5 There is only one research unit working in one part of this wide area; for the remainder, the coastal engineering profession indulges in educated guesswork or relies on the client to define his requirements. Considerable fundamental research is required on ship motions while berthing and at berth and on mooring forces. The design of floating breakwaters, which could be cheaper than conventional stone breakwaters in some situations, also needs to be investigated.

Dispersion and containment of effluents

22.6.6 There have not so far been any major oil spills or major discharges of pollutants in Australian coastal waters and consequently research into dispersion or containment of these materials has been limited. It is important that, since contamination will inevitably occur whether from ships, pipelines or oil wells, the responsible authorities know how to cope

with the major discharge of pollutants. Much information is available overseas, but work on factors peculiar to Australia which may affect containment or dispersion of pollutants is required.

Off-shore pipelines

22.6.7 The number of off-shore pipelines, both as outfalls for sewerage systems and as cooling water intakes for power houses and industrial processes, is increasing. Fewer in number, but of great economic importance, are the seabed pipelines that transport oil and natural gas to shore. The consequent problems range from the forces experienced by the pipelines to the methods of constructing them. There has been practically no research (theoretical, laboratory or field) in Australia in this area. Considerable laboratory research has been carried out overseas and it would therefore seem desirable for Australian research to use the overseas results and to be at prototype scale.

Off-shore development

22.6.8 If standards for off-shore development in the conditions occurring in Australian waters are to be established, a large R&D effort will be required. The weather, sea-state and soil foundation conditions in many locations around Australia are quite different from those occurring, for example, in the Gulf of Mexico, the North Sea or on the Californian coast. Thus it is not always possible for oil companies to transfer technology and design from these locations to Australian waters. Certifying agencies, such as Lloyds or Det Norske Veritas, have been established in Europe mainly for purposes of control in the North Sea, and they may not have experience appropriate to Australian conditions. For all these reasons, oil companies or Government institutions need to undertake appropriate R&D to decide about adopting, adapting or rejecting overseas technologies or designs.

22.6.9 The Bass Strait oil production platform has already had its share of problems because of unexpected behaviour of the foundations. Overseas there have been many failures as, for example, when technology developed in the Gulf of Mexico was applied in the North Sea. Reliance on overseas certifying agents could lead either to conservative design, based on North Sea conditions with a resultant increased cost in oil production, or to inappropriate or even unsafe design because of the long-period waves common on the Australian coast.

22.6.10 If Australia is to develop the capability to control off-shore mining it needs to take action now to train engineers and to provide R&D facilities. A worthwhile effort would require a large professional group with adequate support funds and facilities. Industry co-operation and assistance would be necessary.



CHAPTER 23

EARTH SCIENCES

Photograph: Complexly-folded metasedimentary layers crop out on the north facing cliffs of Mt Trail overlooking Amundsen Bay, Enderby Land, Australian Antarctic Territory. Joint geological field parties from the Bureau of Mineral Resources and Australian universities are at present unravelling the complex tectonic and thermal chronologies of these rocks. (Photograph courtesy University of Adelaide).

CHAPTER 23

EARTH SCIENCES

23.1 DEFINITION OF AREA COVERED

23.1.1 This chapter is concerned with the major geoscience disciplines of geology, geochemistry and geophysics which have the scientific objective of increasing man's knowledge of the history, structure and composition of the solid earth, and the economic objective of providing a data base and conceptual framework for use in the exploration for and development of mineral resources. Brief mention is made of a neglected field on the Australian scene - marine geoscience - which is treated in detail in Chapter 21 ('Marine Sciences').

23.1.2 A strict definition of what is research and what is development in the geosciences is difficult. Appendix 23.1 is an abstract from the OECD 'Frascati Manual' which presents detailed guidelines on the definitions of R&D in this controversial and difficult area. In the universities, new studies of crystallography, deep-earth structure and palaeontology add to the general advancement of knowledge and are clearly research; in government institutions and in mining companies much of the work might be called strategic mission-oriented research. But if a company drills a hole, is that research or not? At the time the hole is drilled the work may be quite routine especially if it is one of many holes sited to map out the extent and grade of a new ore body. But on the time scale of 5-10 years this kind of information contributes to form the data base from which a whole new way of thinking about the general principles of ore genesis may emerge. On a similar time scale, information of this type also produces a very noticeable change in the understanding of the geology of the continent as a whole. This kind of routine work is extremely expensive and occupies many man years of activity yet it is not strictly research. However, part of this activity has to be counted as a very significant contribution to the national research effort. The problem is considered again in sections 23.3 and 23.4. The expenditure on geoscience research within government, university and industrial establishments in 1976 amounted to just under \$20million. However, the amount of \$20million includes only \$1million from industry and omits any contribution from the \$182million spent by government and industry on exploration in 1975-76 (see Table 23.1). No figures exist to enable the research component of exploration expenditure to be estimated; however arguments in section 23.3 suggest an R&D expenditure around \$26million; ASTEC stresses that this is simply the best guess that can be made.

23.1.3 With a continental land surface of approximately 7.8 million square kilometres and an off-shore responsibility (to the 200 mile limit) of about the same area again, much research and development is required if

the geological framework of Australia is to be fully understood and utilised. Mapping at a scale of 1:250,000 is almost complete; but it will be many decades before Australia can be said to have been adequately mapped. In general, where a new research or exploration project is instigated, new geological maps at a scale much larger than 1:250,000 have to be prepared from the beginning [1].

23.1.4 The understanding of the geology of a country or a continent does not stop at geographical boundaries. Australia must consider the geology of the Southern Ocean and the adjacent part of Antarctica to the south, and of Indonesia and Papua New Guinea to the north especially in view of the potential of major petroleum fields on the North West Shelf or on offshore Antarctica. The Indonesian region is one of the most interesting and important areas for understanding major geological processes. With the advantage of proximity to that region and their detailed knowledge of the geology of the Australian area, scientists in Australia are ideally placed to be world leaders in understanding the fundamental processes that operate within the Earth and produce gross changes to the surface of the Earth.

23.2 BACKGROUND

23.2.1 Since 1960 there has been a ten-fold increase in the value of mineral (including petroleum) production in Australia from \$360million p.a. to near \$4,000million p.a. Expressed as a percentage of the gross domestic product (GDP), this represents an increase from 2.5% to 5.5%. These statistics include activities up to and including the first product, but exclude the value derived from further processing.

23.2.2 Mineral exploration in Australia since the Second World War has resulted in the achievement of almost complete self-sufficiency in minerals. Today, Australia's known reserves of bauxite, coal, iron ore, manganese, nickel and mineral sands are very large, and those of copper, lead, zinc, tin, silver and salt are more than adequate for domestic needs; Australia is a major exporter of each of these commodities. Uranium reserves are among the world's largest and there is also considerable potential for export of phosphate rock. The main mineral deficiencies are chromite, magnesium, molybdenum, potash, sulphur, diamonds and certain grades of asbestos, and of coals suitable for some metallurgical applications. The main fuel deficiency is in petroleum, which is by far the major item of mineral imports. In 1975, domestic production supplied about 71% of estimated consumption of crude oil. The heavier crudes account for 30% of demand and must be imported. Indigenous production of oil is expected to peak in the next year or two and to begin a sharp decline from 1981. It is forecast that Australia will regress from its present 70% self-sufficiency to 45% or less in 1985.

23.2.3 An indication of the significance of the mineral industry to the Australian economy may be gauged from the following: in 1976-77 the value of Australian mineral (including fossil fuel) production was \$3,864million (5.5% of the GDP). This figure can be expected to increase markedly, especially when oil exploration and discovery rates pick up and reach the levels of previous years. The mining industry in 1975-76 comprised 1,267 establishments employing 67,609 workers - 1.4% of the workforce. Salaries and wages paid amounted to \$782million; royalties levied totalled \$177million. The mineral and fossil fuel commodities are export earners of substantial rank - accounting for about 29% of total exports (\$9,556million in 1975-76). In exploration \$182million was expended in the search for natural resources, mainly by industry; about one-third was devoted to petroleum prospecting and the rest to minerals (see Table 23.1). Geological and geophysical costs accounted for about 50% of the total exploration expenditure; all other expenditures are committed on the results of the geoscience component. These figures, and other statistics available from the Australian Bureau of Statistics, emphasise the significance and consequences of the exploration and exploitation industries and their growing importance in the economy generally and in the balance of trade in particular.

TABLE 23.1
BREAKDOWN OF EXPLORATION EXPENDITURE
ACCORDING TO COMMODITY 1975-76 (\$million)

	<u>Industry</u>	<u>Government</u>	<u>Total</u>
Mineral Sands	3.89	Breakdown Not Available	
Uranium	9.18	"	
Other Metallics (a)	73.60	"	
Coal	6.30	"	
Construction			
Minerals (b)	0.31	"	
Other Minerals	6.71	"	
Sub-Total	<u>99.99</u>	<u>17.16</u>	
Petroleum	59.99	4.94	
Total	<u>159.98</u>	<u>22.10</u>	182.08

(a) Includes bauxite, copper, gold, iron ore, lead, manganese, nickel, tin, zinc, etc. (b) Includes aggregate, blue metal, gravel, sand, etc., and any other stone used for construction purposes.

Source: Australian Bureau of Statistics : Mineral Exploration, 1975-76.

23.2.4 The potential for the future is enormous: the value of Canadian mineral production in 1975 was \$10,151million. This represents \$1,017/sq km taking the area of Canada as 9.976 million sq km. Although not strictly comparable, the equivalent figure in 1975-76 for Australia was only \$495/sq km. The two countries are geologically very similar and there is no reason why similar mineral discoveries should not be expected. The difference in the mineral income per unit area is not solely due to differences in exploration policy since parts of Canada have a much better established infra-structure than Australia and the political and economic structure is different in the two countries. However, the fact remains that the local geological potential is great.

23.3 ORGANISATION, POLICIES AND FUNDING

ORGANISATION

23.3.1 The organisations undertaking R&D in this area fall into four groups, Commonwealth Government, State Governments, tertiary institutions and industry. In general there is complementary work being undertaken by each sector.

23.3.2 The Bureau of Mineral Resources, Geology and Geophysics (BMR) is a Division of the Department of National Development. It is the national geological survey and its prime responsibility is to provide basic information on the geological framework and mineral resources of the Australian continent and its off-shore margins and of its Territories, as a basis for further research, exploration, policy formulation and management at the national level. The work of BMR is wholly directed at geoscience studies; it undertakes field and laboratory research in geology and geophysics and carries out a continuous review of the mineral industry. The Bureau comprises five branches - Geological, Geophysical, Petroleum Exploration, Mineral Resources and Operations. About half the staff of 550 are professional geoscientists and the annual budget is about \$12million.

23.3.3 The CSIRO Minerals Research Laboratories (MRL) comprise the Divisions of Mineral Engineering, Mineral Chemistry, Process Technology, Mineral Physics, and Mineralogy and the Fuel Geoscience Unit. MRL employs about 500 people of which about half are professional geoscientists, and has a total annual budget of about \$11million. Of the six major programs in MRL three (Exploration Methods, Mineralisation, and Energy) are relevant to this chapter. The recent 'Report of the Independent Inquiry into the CSIRO' has pointed out that the roles of CSIRO and BMR 'are separate but complementary and there are, both necessarily and desirably, areas of overlap and inter-meshing'. Further co-ordination and consultation between the two bodies has been recommended. The CSIRO Divisions of Applied Geomechanics, Land Use Research and Soils also conduct R&D programs relevant to this chapter.

23.3.4 The Australian Atomic Energy Commission is involved in R&D programs using radioactive isotopes in hydrological and geomorphological studies.

23.3.5 Constitutional responsibility for governmental action rests with the States. Each State and the Northern Territory has its own Geological Survey, this being a part of the respective Mines Department or its equivalent; these assist the State Governments in operating and administering this responsibility. Most State Surveys undertake systematic geological mapping and field research; Queensland, Western Australia, the Northern Territory and to a lesser extent the other States undertake this in co-operation with BMR. Geophysical work done by the States is generally concerned with local surveys in support of the State's mineral industry; large scale operations which require expensive technical equipment are normally done by BMR. The State Geological Surveys range in size from 16 professional staff in the Northern Territory to about 75 in the NSW Geological Survey.

23.3.6 Virtually all Australian universities undertake R&D work in the geosciences, generally through their geology departments, but also in some physics and geography departments. Of note is the ANU's Research School of Earth Sciences with an annual budget (1977) of \$2.1million (including 20 student stipends) and employing 95 people of whom 31 are academics.

23.3.7 The Australian mining industry, through the Australian Mineral Industries Research Association (AMIRA), supports R&D work undertaken by universities, CSIRO, and the Australian Mineral Development Laboratories (Amdel). In 1976-77 AMIRA contracted research to the value of \$430,000, about 15% of which was relevant to this chapter. AMIRA, the South Australian Government and the Commonwealth Government support Amdel which undertakes contract R&D and carries out a small amount of its own research; Amdel possesses a great deal of analytical equipment unique in Australia. Many companies have direct arrangements with universities, CSIRO and Amdel for work in specific areas of interest.

23.3.8 Detailed descriptions of many of the organisations mentioned above, and others, may be found in Chapter 24 ('Mining Engineering and Mineral Processing').

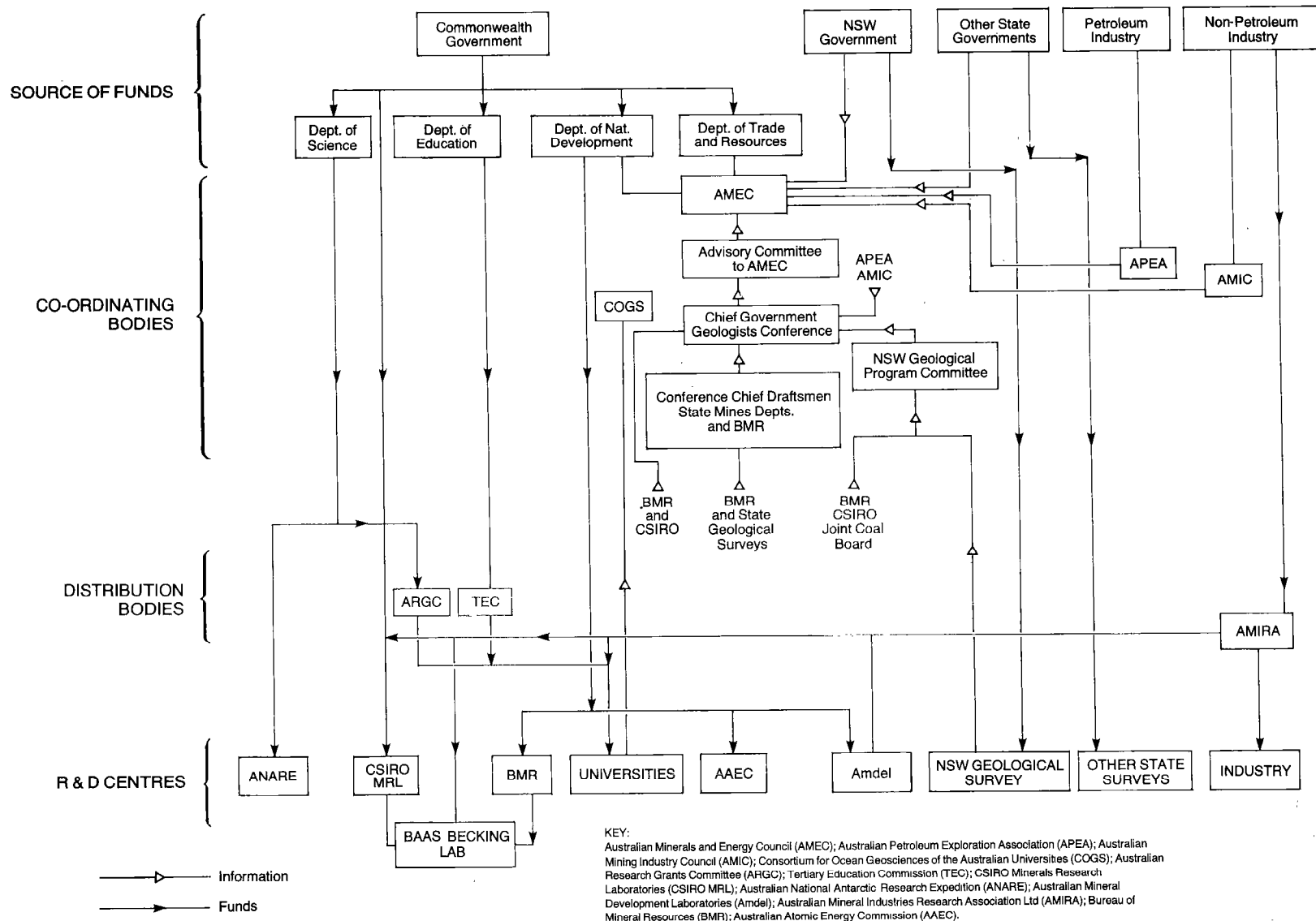
23.3.9 The major professional bodies in the area of geoscience that operate in Australia are the Geological Society of Australia (membership 2834), the Australasian Institute of Mining and Metallurgy (membership 6403), the Australian Society of Exploration Geophysicists (membership 482), the Petroleum Exploration Society of Australia (membership 750) and the Association of Exploration Geochemists (membership 43). A number of professional journals emanate from these bodies - the Journal and various special publications of the Geological Society of Australia, The Australian Geologist, Alcheringa, Proceedings of the Institute of Mining and Metallurgy, The Bulletin of the Australian Society of Exploration Geophysicists, and the Australian Petroleum Exploration Association (APEA) Journal. There is limited involvement by geoscientists in the Australian Academy of Science (in 1977, 6% of Fellows of the Academy were geoscientists) and the Australian Academy of Technological Sciences.

POLICIES

23.3.10 There is no defined overall policy on geoscience research in Australia and, as a result, very little co-ordination of activity. Responsibility for the funding and performance of geoscience research in Australia is widely dispersed over numerous national and State government authorities, the universities, colleges and institutes of technology and the fossil fuels, mining and quarrying industries. Appendix 23.2 lists some of these organisations and Figure 23.1 is an attempt to illustrate some of the interactions involved. Many interactions are not included; in particular, those to do with coal research have been omitted but may be found in Figure 24.1 in Chapter 24. NSW is singled out in this Table because it is the only State that has so far developed a co-ordinating body. As a fleeting glimpse at the complexity: the State Geological Surveys are responsible to the State governments there being only limited interaction between Surveys; the universities are funded in two main ways, namely, through the Tertiary Education Commission and, through the Australian Research Grants Committee (ARGC), by the Department of Science; the BMR is responsible to the Department of National Development and CSIRO is a statutory authority responsible to the Minister for Science.

23.3.11 Australia's involvement in international geoscience displays similar complexity and lack of co-ordination. The Australian Academy of Science has initiated exchanges with the Academia Sinica (Peoples Republic of China). On the non-governmental side the International Council of Scientific Unions (ICSU), Australia, adheres through the National Committees sponsored by the Australian Academy of Science to the International Union of Geodesy and Geophysics (IUGG), the International Union of Geological Sciences (IUGS) and the following relevant ICSU committees: the Scientific Committee for Oceanic Research (SCOR), the Scientific Committee for Antarctic research (SCAR) and the International Geography Union (IGU). There is considerable overlap between the functions of these national committees and their sub-committees and at the same time an almost complete lack of inter-communication. The major learned society in Australian geoscience, The Geological Society of Australia (which has lately been much concerned about geoscience policy) is represented in its own right on only one of these Academy Committees. A revision of this committee structure was requested by the National Committee for Geological Sciences some years ago and is scheduled to occur later this year. There are also National Committees for Geochemistry, Cosmochemistry and Mineralogy, for the International Geological Correlation Program (IGCP) (run by the Department of Education's National Commission for UNESCO), for Geography, Hydrology, Pacific Science, Antarctic Research and for Quaternary Research. These fields are covered by Associations affiliated to IUGS or other ICSU bodies. This makes a total of 10-11 National Committees in the geosciences field!

23.3.12 No machinery exists that would provide an overview of this activity and a comprehensive, carefully formulated, national, geoscience policy does not exist. One body that might be expected to oversee policies is the Australian Minerals and Energy Council (AMEC) whose membership consists of the Minister for National Development, the Minister for Trade



and Resources and the State Ministers for Mines. However, AMEC meets infrequently and has little interaction outside of groups directly associated with its membership.

23.3.13 Despite this inadequate co-ordination of organisation, the Commonwealth and State Government bodies have fairly clear functions with regard to their research projects; these are reviewed from time to time but mainly by internal panels. Agreements exist between BMR and the State authorities (particularly those in Queensland, Western Australia and the Northern Territory) with regard to co-operative projects.

23.3.14 The annual Chief Government Geologists' Conference, a committee which reports to the Advisory Committee of the Australian Minerals and Energy Council, is a forum where State authorities and the BMR co-ordinate future projects. There are no formal agreements whereby government authorities and the university or industrial sector co-ordinate projects; although there is an extensive network of informal person-to-person contacts and fairly widespread joint use of equipment.

23.3.15 Notwithstanding problems created by this cumbersome structure, Australian scientists, as individuals, participate actively in international research projects through working groups and membership of international commissions, sub-commissions and committees such as the IUGS Commission on Stratigraphy and the Committee on Geological Education. For example, Australia participates in about 28 of the 62 currently accepted IGCP projects and the level of participation in the Geodynamics Project (IGC) is also high. Personal participation in IPOD (Deep Sea Drilling) has been on a satisfactory level but organisational membership requires an investment of \$1million which is not available, and Australia therefore has no influence on the all-important programming. There are other sporadic, international activities such as the World Petroleum Congress, the Circum-Pacific Energy and Mineral Resources Conference, and the statutory international activities of the BMR such as participation in the Commission for the Geological Map of the World and representation in and assistance to the Economic and Social Commission for Asia and the Pacific (ESCAP) and other development aid. A listing of councils and committees relevant to geosciences in Australia is presented in Appendix 23.2.

FUNDING

23.3.16 Estimates of the total direct expenditure and professional effort in 1976 on geoscience R&D in Australia are indicated in Table 23.2.

23.3.17 As indicated in Table 23.1, total expenditure by industry on exploration in 1975-76 was \$160million. This included exploration for all mineral resources including petroleum. Of this amount, about 50% was spent on direct geological and geophysical studies, the remainder being spent on drilling, logistics and administration. Of the \$160million, \$89million was spent in the private sector on exploration for uranium, metalliferous deposits and coal. The remainder was spent on exploration for petroleum products, non-metalliferous deposits, mineral sands and

construction materials (Table 23.1). In Table 23.3 an attempt has been made to estimate the contribution to R&D from this expenditure of \$89 million; an amount of \$20.5million is arrived at. This number is quite uncertain; some industrial spokesmen claim a number as low as \$1million and others as high as \$50million. Estimation of the amount is subject to the uncertainties mentioned above (see 23.1.2). \$20.5million corresponds to about 400 professional man-years. Another \$60million was spent during 1975-76 in petroleum exploration which is relatively expensive compared to metalliferous exploration; 10% of this (\$6million) is taken as an R&D contribution - about 60 professional man-years of activity, although these estimates may be too high when one considers the very large expenditures involved in seismic surveying and drilling.

TABLE 23.2
ESTIMATES OF DIRECT R&D EXPENDITURE
AND PROFESSIONAL MANPOWER

	<u>Cwlth</u> <u>Govt</u>	<u>State</u> <u>Govts</u>	<u>Tertiary</u> <u>Institutions</u>	<u>Industry</u>	<u>Totals</u>
Expenditure (\$million)	8.6	6.1	4.3	0.9	19.9
Professional Man-Years	281	200	174	20	675

Note: R&D expenditures in this chapter are operating costs (including salaries) only. Overhead costs are excluded. See also footnote to Table 23.4

23.3.18 Thus, although only \$0.9million is formally identified by industry as geoscience research there are indications that an additional \$26.5million is expended by industry on R&D. For several reasons, ASTEC has not attempted to determine the corresponding R&D component of the \$22million spent on exploration by government (see Table 23.1); it therefore accepts that the total R&D figures given for the government sectors are low. The total research expenditure and manpower situation is summarised in Table 23.4. In this table, it is apparent that CSIRO, BMR and the State government bodies operate at about \$30,000 per professional man-year and universities at a slightly lower rate of \$25,000 per professional man-year. Industry operates at a greater rate of about \$50,000 or more per professional man-year.

23.4 DESCRIPTION OF MAJOR R&D PROGRAMS

23.4.1 The broad spectrum of geoscience R&D has been divided into three broad groups, namely,

TABLE 23.3
ESTIMATED CONTRIBUTION OF PRIVATE MINERAL EXPLORATION FUNDS TO
GEOSCIENCE R&D 1975-76 (EXCLUDING PETROLEUM)

Category	Expenditure \$million(a)	Estimated Expenditure on Uranium, Metalliferous & Non-Metalliferous Exploration (b)	Estimated contribution to regional and period studies research		Estimated contribution to mineral deposit research		Estimated contribution to geophysical research & geoscience technology	
			Expenditure (\$million)	% of Notional Total (Col.2)	Expenditure (\$million)	% of Notional Total (Col.2)	Expenditure \$million	% of Notional Total (Col.2)
Production leases, non-drilling	5.4	4.8			0.5	10		
Production leases, drilling	9.7	8.6	0.1	1	0.1	1	0.1	1
Other areas, non-drilling	64.0	57.0	17.1	30	0.6	1	0.6	1
Other areas, drilling	20.8	18.5	0.2	1	1.0	5	0.2	1
TOTAL	99.9	88.9	17.4		2.2		0.9	

(a) Source: Australian Bureau of Statistics, Mineral Exploration 1975-76.

(b) No detailed figures are available to enable the numbers in this column to be accurately calculated. They are taken as 89% of the previous column since the expenditure on uranium, coal and metalliferous mineral exploration is 89% of the total non-petroleum exploration costs.

Group 1 Studies concerned with the history, structure and composition of the earth

Group 2 Studies concerned specifically with mineral resources

Group 3 Studies concerned with the application of geoscience

In addition there is a brief description of the Antarctic geoscience research.

23.4.2 In a very broad manner, this grouping passes from studies that are devoted solely to the general advancement of knowledge (basic research), through strategic mission-oriented research (basic/strategic) to tactical problem-solving research (applied). As examples of the use of these three terms: the study of the crystal chemistry of copper minerals as a group would be classified as contributing to the general advancement of knowledge (basic), the study of copper mineralisation in NSW would be strategic mission-oriented research (basic/strategic) whereas the study of copper mineralisation near an ore body such as that at Captain's Flat in NSW in an attempt to discover a new ore body would be tactical (applied) research. Exploration is a wide spectrum of activity that may be strategic research or tactical research or routine at the time it is done but ultimately, over a long time, contributes to the general advance of knowledge.

23.4.3 Details of expenditure are laid out in Tables 23.5, 23.6 and 23.7. Because of the uncertainties associated with estimating the contribution to R&D from exploration activities, the expenditure in each R&D activity is expressed in Table 23.7 as a percentage of a total expenditure of \$19.9million, and secondly (final column) as a percentage of the total of \$46.4million arrived at if \$26.5million is included as a contribution from exploration. Any contribution to R&D from exploration concerned with the particular activity under discussion is added to the R&D expenditure on that activity before calculating the percentage relative to the total of \$46.4million. The true percentage is presumably somewhere between these two extremes. In addition, there is some inconsistency in the level of information available. In general, about 50% of the time of university staff has been allocated to R&D activities and in other sectors, a figure of \$25,000 for a full professional year has been used in estimating manpower.

EARTH HISTORY, STRUCTURE AND COMPOSITION

Group 1: This group includes the categories: Earth Structure and Physical Properties; Regional Studies; Petrology, Mineralogy and Geochemistry; Sedimentology and Surface Geology; Palaeontology; and Marine Geosciences. A large proportion of the expenditure in Group 1 is allocated to Regional Studies with the remainder being shared almost uniformly by the remaining categories - see Table 23.7. This table also shows that the substantial contribution by industry is essentially allocated to Regional Studies.

TABLE 23.4
ESTIMATED EXPENDITURE ON GEOSCIENCE RESEARCH
AND MANPOWER. 1975-76

	Expenditure \$ million	as % of earnings from mineral production(a)	% of GDP(b)	Professional man-years
Commonwealth Government (CSIRO+BMR)	8.6	0.22	0.012	281
State Governments	6.1	0.16	0.009	200
Universities	4.3	0.11	0.006	174
Formal Research indicated by industry in ASTEC survey	0.9	0.02	0.001	20
Sub-total	19.9	0.51	0.028	675
Additional Research activity intimately associated with exploration for minerals, petrol- eum, etc.	26.5	0.68	0.038	460
Totals	46.4	1.19	0.066	1135

a: ex-mine value of \$3,864million, b: GDP for 1975-76 = \$70,000million.

Note: Although Project SCORE [3] did not specifically gather data on geoscience R&D expenditure in its last survey (1973-74), their estimates on some areas of expenditure are at variance with some of the above figures e.g. their estimate of the Commonwealth expenditure in 1973-74 is \$11million. See also 23.3.18.

Earth structure and physical properties

23.4.4 One aspect of this program is concerned with the study of major structures which are of crustal dimensions; it is also directed at studying the geodynamic, gravitational, geomagnetic and geothermal properties of the earth, and their relationships to large scale structures, structural trends and mineral occurrence. About a quarter of the R&D effort is contributed by BMR and the other three-quarters by universities, particularly the Australian National University (ANU), but also Adelaide, Flinders, Macquarie, Melbourne, New England, Sydney Universities and the University of Queensland.

TABLE 23.5

SUMMARY OF EXPENDITURE (\$000) ON GEOSCIENCES R&D
ACCORDING TO AREA AND SECTOR

Group & Activity	Cwlth Govt	State Govts	Tertiary Institutions	Industry	Totals
<u>Group 1</u>					
1. Earth Structure	214		707		921
2. Regional Studies	3617	3545	639	195	7996
3. Petrology & Mineralogy	40	65	908	40	1053
4. Sedimentology & Surface Geology	52		539	56	647
5. Palaeontology	234	108	542	30	914
<u>Group Sub-Total</u>	4157	3718	3335	321	11531
<u>Group 2</u>					
6. Metalliferous Deposits	738	554	570	55	1917
7. Oil & Gas	155	95	19	120	389
8. Coal		included in 2 and 4			
9. Non-metalli- ferous deposits		very small			
10. Hydro-geology	501	511	119		1131
11. Resource Assessment	361	836	62	150	1409
<u>Group Sub-Total</u>	1755	1996	770	325	4846
<u>Group 3</u>					
12. Engineering Geology	582	254	141		977
13. Geoscience Technology	2100	150	25	231	2506
<u>Group Sub-Total</u>	2682	404	166	231	3483
<u>TOTAL</u>	8594	6118	4271	877	19860

TABLE 23.6

SUMMARY OF MANPOWER (PROFESSIONAL MAN-YEARS) IN GEOSCIENCES
R&D ACCORDING TO AREA AND SECTOR

Group & Activity	Cwlth Govt	State Govts	Tertiary Institutions	Industry	Totals
<u>Group 1</u>					
1. Earth Structure	7.2		26.4		33.6
2. Regional Studies	106.4	110.2	26.8	3.0	246.4
3. Petrology & Mineralogy	1.0	1.1	33.2	2.0	37.3
4. Sedimentology & Surface Geology	3.5		20.1	1.3	24.9
5. Palaeontology	10.6	5.8	25.2	0.8	42.4
<u>Group Sub-Total</u>	128.7	117.1	131.7	7.1	384.6
<u>Group 2</u>					
6. Metalliferous Deposits	24.3	16.7	25.0		66.0
7. Oil & Gas	6.0	1.3	0.6	3.0	10.9
8. Coal		included in 2 and 4			
9. Non-metalli- ferous deposits		very small			
10. Hydro-geology	15.9	28.3	6.7		50.9
11. Resource Assessment	15.0	21.8	2.5	3.8	43.1
<u>Group Sub-Total</u>	61.2	68.1	34.8	6.8	170.9
<u>Group 3</u>					
12. Engineering Geology	15.3	10.2	6.3		31.8
13. Geoscience Technology	76.3	5.3	0.6	5.8	88.0
<u>Group Sub-Total</u>	91.6	15.5	6.9	5.8	119.8
<u>TOTAL</u>	281.5	200.7	173.4	19.7	675.3

TABLE 23.7
SUMMARY OF ESTIMATED EXPENDITURE ACCORDING TO R&D ACTIVITY

Group & Activity	ASTEC Survey	% of Total Expenditure		
		Industry Con- tribution from Exploration	ASTEC Sur- vey only (see 23.4.3)	Incl.Exploration Contribution
	(\$million)	(\$million)		
<u>Group 1</u>				
1. Earth Structure	0.921	-	4.6	2.0
2. Regional Studies	7.996	17.4	40.2	54.6
3. Petrology & Mineralogy	1.053	)	5.3	2.3
4. Sedimentology & Surface Geology	0.647	) Some of these included in 2, 6, 7	3.3	1.4
5. Palaeontology	0.914	)	4.6	2.0
<u>Group Sub-total</u>	11.531	17.4	58.0	62.3
<u>Group 2</u>				
6. Metalliferous Deposits	1.917	2.2	9.6	8.9
7. Oil and Gas	0.389	6.0	2.0	13.8
8. Coal	included in 2 & 4	included in 2	included in 2 & 4	included in 2 & 4
9. Non-metalliferous deposits	included in 2-very small	very small	very small	very small
10. Hydro-geology	1.131	-	5.7	2.4
11. Resource Assessment	1.409	Probably very considerable but included in 2, 6 & 7	7.1	3.0
<u>Group Sub-total</u>	4.846	8.2	24.4	28.1
<u>Group 3</u>				
12. Engineering Geology	0.977	-	4.9	2.1
13. Geoscience Technology	2.506	0.9	12.6	7.4
<u>Group Sub-total</u>	3.483	0.9	17.5	9.5
<u>TOTAL</u>	19.860	26.5	99.9	99.9

23.4.5 Geophysical observatories and seismograph networks are operated by BMR, ANU and the universities in South Australia, Queensland and Tasmania. BMR operates five complete geomagnetic and seismological observatories in Australia, Papua New Guinea (PNG) and Antarctica as part of the worldwide network. The universities also maintain seismographs as part of the worldwide network and also use systems designed to monitor the smaller Australian earthquakes and as such complement the BMR system; the Riverview Observatory operated by Macquarie University is an important example.

23.4.6 Crustal studies have been undertaken by various groups in Australia using a network of permanent local seismic stations as well as mobile recording stations to record quarry blasts, explosions associated with engineering works and small earthquakes. On a somewhat finer scale the regional gravity survey carried out by the BMR over the whole of the continent, the airborne magnetic surveys which cover about 75% of the continent and the marine surveys which incorporate gravity, magnetic and seismic methods, that have been carried out on a forty kilometre grid off the northern, southern and eastern seaboard of the continent, contain information about medium-sized structures and changes in the bulk physical properties of rocks which are not readily observed in the course of normal geological studies.

23.4.7 Although the earthquake risk in Australia is small there are regions where it is significant and the geological relationships in these areas form much of the seismological R&D in Australia. CSIRO and BMR are jointly undertaking a project to measure the stress field in rocks in earthquake-prone and other areas in an attempt to develop earthquake prediction methods and to establish the regional stress fields across Australia. Monash University is examining recrystallised grain-sizes in ductile fault zones with the aim of quantifying the stress values around fault zones to aid earthquake prediction. ANU and Monash also have projects on stress-strain, creep and related experiments on rocks and minerals under high pressure and temperature.

23.4.8 Investigations into the structure, composition and physical state of the crust and upper mantle [2] using geochemical and geophysical methods are being undertaken by the ANU, BMR and, to a lesser extent, by other universities. Marine geophysical methods are being used by BMR, Flinders University and Sydney University to study crustal and upper mantle structures. Substantial contributions to this area have been made in the Research School of Earth Sciences at ANU in the fields of seismology, palaeomagnetism, heat flow, earth structure and the mechanical characteristics of rocks and minerals; this work is acclaimed internationally and has formed much of the basis for the theory of plate tectonics upon which much geoscientific thought is now focussed.

Regional studies

23.4.9 Geological R&D is all based to a greater or lesser extent on knowledge of the three dimensional and temporal relations of rock units. As this knowledge is the objective of geological mapping it may be regarded as the most basic of all geological research.

23.4.10 During the last two or three decades much of the Australian continent has been mapped at a scale of 1:500,000 or 1:250,000 [1]. The available small-scale maps provide only the most general basis for research, and mapping at 1:100,000 or 1:50,000 scale must be regarded as a long term objective. Limited programs of mapping at 1:100,000 or better are undertaken by the BMR and by the State Geological Surveys and major mining and petroleum exploration companies have also carried out extensive mapping programs as part of their general exploration effort. In general, mapping is not co-ordinated or standardised although the annual Chief Government Geologists' Conference has had considerable success recently in standardising the presentation of maps. The Geological Society of Australia has organised the preparation of the Tectonic Map of Australia and the BMR co-ordinates the preparation of the Geological Map of Australia. Interaction has also occurred in some large projects such as the hydro-geology of the Great Artesian Basin (BMR, Qld, NSW, and the Northern Territory) and the stratigraphy and sedimentology of the Georgina Basin (BMR, Qld and the Northern Territory).

23.4.11 As the scale of mapping increases, the value of, and need for, supplementary laboratory studies also increases. At present close co-ordination of field and laboratory studies, like larger-scale mapping, is usually limited to strategic and tactical research programs. Some of these are already being undertaken by the BMR and State Geological Surveys. Others are undertaken by the universities. Mining and petroleum exploration companies also mount strategic and tactical research programs of this type in order to increase understanding of the environments of ore deposition and petroleum accumulation.

23.4.12 This category accounts for about 50% of the R&D expenditure considered in this chapter (see Table 23.7). It includes a contribution of about 65% from industry and a further 25% contributed equally by the BMR and the State Geological Surveys. BMR directs about 65% of its total effort to regional studies. Projects are carried out either as systematic reconnaissance surveys which are designed to provide a broad understanding or as more detailed studies of geologically complex areas of economic potential.

23.4.13 On-shore and off-shore reconnaissance surveys conducted by the Government centre on the BMR. These include geological mapping, airborne magnetic and radiometric surveys, and gravity surveys. It is expected that, in conjunction with the State Geological Surveys, geological maps at 1:250,000 scale of the entire continent will be available by 1980. About 75% of the continent has been covered with airborne magnetic surveys. The continental margin, out to the 4000m isobath, has been covered by a seismic, gravity and magnetic survey at the spacing of 40 km except for the margins bordering northern Australia, the Great Barrier Reef and Bass Strait.

23.4.14 Reconnaissance projects being currently undertaken by BMR include continuation of airborne magnetic and radiometric surveys, geological mapping in the Canning Basin and Antarctica, and participation with overseas institutes in marine geophysics and bottom sediment sampling.

23.4.15 The more detailed studies of sedimentary basins and metalliferous provinces are integrated multi-disciplinary investigations involving semi-detailed geological mapping, and geochemical sampling and analysis of soils, rocks, and streams, detailed ground geophysical surveys, and laboratory studies into the age, composition and genesis of the country rock and associated mineral and hydrocarbon deposits. The main aim of these studies is to assess the potential of those areas where lack of sufficiently detailed knowledge currently precludes a fair assessment of resources.

23.4.16 Provinces currently being studied by BMR, generally in co-operation with the appropriate State or Territory Geological Survey, are Lachlan Belt (NSW), Arunta Block (NT), Georgetown (Qld), Georgina Basin (Qld, NT), Mt Isa Block (Qld), McArthur Basin (NT) and the Pine Creek Block (NT). Province and basin studies are becoming increasingly important components of the BMR's program and, in 1976, represented about 77 man-years of effort with an estimated expenditure of \$1.6million.

23.4.17 The Mines Department of each State confines its R&D activities to areas within its respective State boundaries, with a minor contribution off-shore. South Australia, Tasmania and Queensland each contribute about 65% of their total R&D effort in the geosciences to regional studies and NSW and Western Australia just under 50%. The State Mines Departments or their equivalents concentrate most of their effort on geology-based projects and rely to varying degrees on BMR to provide the geophysical contribution.

23.4.18 Major projects currently undertaken by the States are:

- | | |
|-------------------|--|
| New South Wales | . geological field research of the Cobar-Condobolin and the Broken Hill regions; study of the Silurian System of NSW. |
| South Australia | . integrated geological and geophysical studies in Cainozoic sediments of the Great Artesian Basin; regional stratigraphy of Adelaidean sediments; regional tectonics of Precambrian basement. |
| Western Australia | . geological field research in the Canning, Carnarvon, Officer and Perth Basins and selected parts of the Precambrian Shield. |
| Tasmania | . stratigraphic and hydrological evaluation of the Parmeena Super-Group in the Midlands and southern Tasmania; the relationship of the Precambrian rocks of the Tyennan Geanticline and the Eocambrian of SW Tasmania; |

geological environments of the Eocambrian and Cambrian Smithton Basin and regional gravity and magnetic surveys

Queensland and Victoria

. regional geological surveys.

23.4.19 Not all universities undertake research into regional studies and collectively they represent about 10% of the total Australian effort. Where undertaken they involve more detailed studies of particular problems, using the regional information provided by BMR, by State Geological Surveys and by mining companies as their starting point. Major projects are:

University of Adelaide

. the Precambrian-Cambrian boundary in central and southern Australia; the nature and extent of Late Precambrian glaciations in southern and central Australia and their usefulness for intracontinental correlations; regional structural analysis of the Willyama orogenic domain in relation to the Broken Hill ore body; structural and metamorphic studies in Eyre Peninsula and in Antarctica; geochronological studies of Archaean and Proterozoic granitic rocks and associated supra-crustal rocks; tectonics of Australia.

Australian National University (ANU) and Macquarie University

. the sequence of structure of sedimentary and igneous rocks, their origins and relation to major crustal features in the Lachlan Fold Belt.

James Cook University

. Cainozoic volcanic provinces of north Queensland and various metamorphic terrains.

University of New England

. study of areal and structural geology of selected areas in the New England and Lachlan Fold Belts; tectonic studies of Australia, Antarctica, New Zealand, SW Pacific and Indonesia.

Melbourne University

. geochemistry and geochronology of the WA Shield; separation of the Australian Plate from Gondwanaland.

23.4.20 Expenditure on non-petroleum exploration by the private sector was \$100million in 1975-76. A major proportion of this amount, namely \$84.8million, was spent outside production leases. Most of the resulting work was carried out on exploration tenements which carry a statutory obligation to report results to Government. State Government Mines Departments hold by far the greater amount of such results. A high turnover of tenements means that a large proportion of results becomes available for open file release. Further studies are then initiated by the explorer often using specialised research staff, to select new areas of exploration. Research of this kind, which is not carried out on exploration tenements, may lead to the development of new concepts but the results do not have to be published, and in fact rarely are.

23.4.21 An estimate of the minimum dollar value of exploration results which qualify as contributions to regional studies research under the definition used in this paper is given in Table 23.2 based on figures from the Australian Bureau of Statistics. The major contribution is an estimated 30% of the non-drilling expenditure outside production leases. This comprises basic geological mapping, together with geochemical and geophysical surveys as well as specific regional syntheses, correlations and comparisons. A small proportion of drilling outside production leases, estimated at perhaps 1% of the expenditure, also qualifies under the above definition. This would mainly comprise wildcat or stratigraphic holes which extend or refine regional knowledge. A very small, nominal amount of exploration on production leases contributes to regional studies. The total contribution to regional studies of \$17.3million (Table 23.3) should be taken with caution.

23.4.22 Professional man-years represented by the expenditure of \$17.3 million cannot be accurately calculated. However, a rule of thumb figure of about \$50,000 per professional man-year was generally used in the exploration industry in 1975-76 and this would return an equivalent figure of about 350 man-years.

Petrology, mineralogy and geochemistry

23.4.23 Petrology, mineralogy and geochemistry relate to the occurrence, origin, physical and chemical properties of the materials that comprise the solid earth and other terrestrial bodies. These fields represent between 2.3% and 5.3% of the R&D covered in this chapter (see Table 23.7). A component of petrology and mineralogy research is present in other categories such as regional studies, mineral resources and earth properties.

23.4.24 More than 80% of basic research in petrology and mineralogy is undertaken by the university sector. The CSIRO Minerals Research Laboratories, the BMR and State Geological Surveys carry out mainly strategic/tactical oriented research. A small proportion of petrology and

mineralogy R&D is done by industry and industry-sponsored groups such as AMIRA and the government/industry-sponsored Amdel.

23.4.25 All the major universities (and some other tertiary education institutions) maintain petrology and mineralogy research programs. In recent years the major contributor has been ANU (primarily the Research School of Earth Sciences), which is the best equipped and funded group. ANU has achieved international prominence in fields such as experimental studies of the mineralogy and petrology of the crust and mantle of the earth and the moon, and isotopic, geochronologic investigations aimed at elucidating the evolution of earth and moon.

23.4.26 Macquarie and Monash Universities and the Universities of New South Wales and Tasmania also have high-temperature, high-pressure experimental programs. These groups are studying such problems as the genesis of basalts and island arc magmas, phase relations in metamorphic systems, the evolution of granitic magmas, the hydrothermal alteration of rocks and the transport and deposition of ore-forming components.

23.4.27 Major petrological research in the universities involves field and analytically-oriented investigations. ANU and La Trobe and Macquarie Universities are examining the nature, origin and evolution of granitoid bodies in the Lachlan Fold Belt while Macquarie University is also examining similar bodies in the New England Fold Belt. The Universities of Adelaide and Western Australia have large field, geochemical and petrological programs underway on the volcanic and plutonic complexes of the Archean Shield, with special reference to nickel mineralisation. Monash University is working on metamorphism and mineralisation in the Willyama complex around Broken Hill (NSW). Studies of metamorphic rocks at the University of Queensland have concentrated on high grade metamorphism in the shield areas. Sydney University is engaged in investigation of low-grade metamorphism and is compiling the metamorphic map of Australia as part of an international project. Major studies on geochemistry, petrology and petrogenesis of modern and ancient volcanic rocks are underway at the Universities of Tasmania, Queensland, Melbourne, New England and at Monash and Macquarie Universities.

23.4.28 Specialised mineralogical research is undertaken by the universities on a more limited scale. Projects include clay mineral studies (NSW), electron microscopy of rock forming minerals (Monash and ANU), and x-ray crystallography (James Cook, Sydney, Adelaide, ANU).

23.4.29 Radiogenic isotope studies applied to petrology and geochronology are performed at ANU and at the University of Adelaide. Fission-track dating is done at the Universities of Melbourne and New England. The University of Queensland performs stable-isotopic work on metamorphic rocks and mineral deposits, while workers at Adelaide and Tasmania conduct stable-isotope studies associated with ore genesis using outside facilities. The University of Melbourne is also developing the ion microprobe as a geological dating tool.

23.4.30 Theoretical work in aqueous geochemistry work on rock-water interaction and ore deposition involves a few workers at La Trobe and Monash Universities and at the University of Tasmania. Other theoretical geochemistry and petrology is mostly done as part of large projects.

23.4.31 The State Mines Departments collectively expend about 8% of the petrology and mineralogy effort in Australia, this being about the same as that expended by BMR and industry. Most of this effort is in support of regional studies and is an essential contribution to the understanding of the materials that make up the earth's crust (and their relationships) in Australia and its territories. The BMR, for example, has petrological projects in progress on Antarctica, Central Australia, Western Australia; in the volcanic and ultramafic belts in Papua New Guinea; and in the potentially diamondiferous kimberlites of the Australian shield.

23.4.32 Petrology, mineralogy and geochemistry R&D undertaken by CSIRO (mainly Minerals Research Laboratories) covers a very wide range; it overlaps with mineral resources and mineral processing (Chapter 24).

Sedimentology and surface geology

23.4.33 These domains of geosciences are concerned with the nature, processes and environments of formation of ancient and modern sediments, surface materials which mantle the landscape and landforms.

23.4.34 Between 1.4% and 3.3% of Australian geoscience R&D expenditure is attributable directly to sedimentology and surface geology (see Table 23.7). However, there is a component of sedimentology (perhaps 30%) in many regional studies and in exploration for fossil fuels and minerals. Activity is widespread in universities, the BMR and State Geological Surveys. Further work (perhaps to the extent of \$0.5million), principally on surface geology, occurs in CSIRO (Divisions of Soils, Land Use Research and Applied Geomechanics) and university geography departments.

23.4.35 The relative research emphasis as between ancient sedimentary rocks, young sediments and surface materials varies greatly among geoscience institutions. Fundamental studies of sedimentary and surface processes are few, being confined to the CSIRO Division of Soils, the BMR and certain universities. Of the research projects reported in the 1976 Sedimentological Newsletter of the Geological Society of Australia, over 90% are focussed on particular areas or rock units. 60% of all projects are concerned with young (Upper Tertiary and Quaternary) materials, principally coastal and shallow marine sediments which are studied by several seaboard universities, the BMR and some State authorities. The major centre for study of continental surface materials is Canberra, with eight institutional units involved. Detailed sedimentological studies of ancient rock sequences account for less than 20% of projects. These are predominantly studies by graduate students, notably at the Universities of New England and Adelaide.

23.4.36 Although studies of modern marine sediments are numerous (the Consortium for Ocean Geosciences, COGS, maintains a register), they are limited in both scope and funding. Co-ordination of these studies is just beginning under COGS' auspices. A systematic survey of the sediments on the continental shelf and margin is being made by BMR and is about 30% completed as regards the sampling program.

23.4.37 Regional surveys of the Australian landscape have been undertaken by two Divisions of CSIRO. These take the form of terrain analyses and land systems maps and reports.

Palaeontology

23.4.38 This domain of geoscience embraces studies of fossil plants and animals. Part of the research undertaken is directly related to more general regional studies and relevant expenditures are reported in that section. Research attributable to pure palaeontology is between 2.0% and 4.5% of geoscience R&D (see Table 23.7). The distribution of this effort is 60% in universities (26 professionals), and 40% by BMR (14 professionals), the State Mines Departments (14 professionals), and museums (11 professionals).

23.4.39 In the BMR and State Geological Surveys research includes systematic description and tabulation of fossils with a view to determining their age ranges and the course of evolution, and to evaluating past sedimentary environments. Much of this research is undertaken in conjunction with geological mapping programs and the correlation of rock sequences both Australia-wide and internationally.

23.4.40 Similar research is undertaken in museums and universities with, however, a concentration on particular groups of organisms, geological provinces or geological periods. Also included are studies in theoretical palaeontology, the functioning of fossil organisms, their global distribution patterns, reasons for their concentration in certain sedimentary environments and inter-relations of organisms and environment. Macro and micro-invertebrate fossils are widely studied, but other groups are less widely catered for. Macroplants are studied at the Universities of New England and Queensland and at the Australian Museum, palynology at the Universities of Queensland, NSW, WA, at ANU and the BMR, and in industrial concerns such as Esso/BHP; vertebrates at Sydney, ANU and Monash universities, the BMR and most museums. The University of Queensland has a major interest in invertebrate biogeography; the Universities of Melbourne and New England in the palaeo-ecology of marine invertebrates; and Macquarie University in invertebrate paleo-biogeography and palaeo-ecology. The BMR and the University of Adelaide have major interests in Precambrian palaeontology. Co-operation between BMR, State Mines Departments, museums and universities is general. Many workers do not confine their studies to Australian material, for the geographic ranges of many fossil organisms transcends national boundaries.

Marine geosciences

23.4.41 This area is covered in detail in Chapter 22. The marine geosciences include marine geology which deals with the composition, structure and history of the surface and sub-surface materials of the continental shelf and the deeper sea-floor and with the processes of sedimentation, alteration and deformation; and marine geophysics which is concerned with the structure of these areas and the physical properties of the materials comprising the sub-surface layers.

23.4.42 Research in marine geoscience is most active in the private sector where R&D costs in exploration for off-shore oil and gas amounted to about \$29million in 1976 and total costs, including production, have averaged about \$101million annually over the last six years. About 50 geoscientists are involved in exploration R&D concerned with petroleum and mining. University research totals about \$1.4million, including salaries, grants and overheads, and is concentrated on near-shore studies due to the lack of ship facilities. University researchers have formed the Consortium for Ocean Geosciences of Australian Universities (COGS). COGS represents 16 university geoscience departments and about 43 scientists. The BMR spent about \$690,000 in 1977-78 on marine geoscience, including salaries, primarily on data processing of geophysical results from the continental margin survey, but its recent budgets have been cut back until marine work represents only about 5% of total costs, whereas it amounted to as much as 20% in the early 1970's. About 25 full-time researchers are employed by BMR on this work. The final group includes State government agencies, mostly the Geological Surveys, which spend about \$375,000 annually on marine research, generally directed toward near-shore engineering, environmental and a few economic problems, such as sub-surface coal deposits in northern NSW. Perhaps a dozen researchers are involved. The body of expertise in marine geology resides mostly in the universities and BMR; most marine geophysics expertise resides in the BMR.

MINERAL RESOURCES

Group 2: This group accounts for about 25% of geoscience R&D and includes the categories: Metalliferous Deposits; Oil and Gas; Coal; Non-metalliferous Deposits; Hydro-geology; and Resource Assessment (see Table 23.7).

Metalliferous deposits

23.4.43 Research on mineral deposits is carried out by Commonwealth and State government agencies, by universities and by industry. The objective is to provide a better factual, and conceptual, scientific framework to assist in the discovery, evaluation, development and assessment of the nation's mineral resources.

23.4.44 Figures indicate that the Commonwealth Government spent \$800,000 on mineral deposit research in 1976. State governments spent \$600,000, of which about half was provided by NSW with SA as the next largest contributor. The universities spent some \$600,000. All universities are involved to some extent but major programs exist at Adelaide, ANU, New England and Tasmania. Industry contributions to mineral deposit research have been estimated in Table 23.3. Production-lease exploration is closely bound up with mineral deposit research as is a modest proportion of expenditure outside production leases. Estimated industry total for 1975-76 is \$2.2million and (on the same basis as for regional studies) this represents about 40 professional man-years. About 9% of the total geoscience R&D effort is expended on research into metalliferous deposits (see Table 23.7).

23.4.45 Genetic investigations of mineralisation and its relationship to geological environment are carried out by the CSIRO Division of Mineralogy, particular emphasis having been given to nickel sulphide and calcrete uranium deposits in Western Australia, and to base metal deposits in the Lachlan Fold Belt of NSW and the west Queensland Proterozoic province. Petrological and geochemical techniques are supported by isotopic research. Experimental studies of model systems relevant to mineralising processes and fluid inclusion research are also carried out. Industry research on mineral deposits covers a very wide range of minerals in every State but, as most work is initially carried out confidentially, little comprehensive current data are available.

Oil and gas

23.4.46 Research into petroleum geology relates to the origin, occurrence, migration, accumulation and exploration for hydrocarbon fuels (liquid and gaseous). Much of the work considered in earlier sections (especially regional studies) is essential, or at least relevant, to petroleum exploration. Most of the research effort outside industry comes from BMR and CSIRO with smaller contributions from some of the Geological Surveys and from several Australian tertiary institutions. Research is primarily aimed at critical factors in the generation of petroleum and at methods of assessing the conditions of Australian sedimentary rocks with respect to these factors.

23.4.47 More specifically, research is directed to the occurrence and nature of source rocks, to the degree of maturity or of diagenetic change which has been attained in the many on-shore and off-shore sedimentary basins, and to the migration and trapping of hydrocarbons (CSIRO, BMR, Universities of Queensland and Wollongong, WA Institute of Technology). The use of soil geochemistry as an exploration tool for hydrocarbons is being investigated by the Geological Surveys of South Australia and NSW, and geochemical methods are also being studied by the CSIRO Fuel Geoscience Unit. Besides conducting research on the origin of petroleum, the BMR makes a continuing study of Australian sedimentary basins with respect to their hydrocarbon potential, and, jointly with CSIRO, is making a systematic assessment of source rocks in Australia.

23.4.48 The major expenditure in petroleum exploration comes from companies, mostly large companies or consortia of an international character. Total exploration expenditure, by companies, for petroleum in Australia was \$60million in 1975-76, of which over \$52million was for off-shore exploration. The exploration expenditure figures have been declining since 1972 (\$60million), but are expected to increase somewhat in 1978. It is estimated that research in petroleum geology in overseas institutions, supported by local subsidiaries of international companies, is equivalent to about 0.5% of the total Australian R&D effort in the geosciences.

Coal

23.4.49 Coal (black and brown) supplies about 42% of Australia's energy needs. As coal also comprises over 80% of Australia's proven recoverable energy reserves, it is virtually certain that it will become the source of progressively larger amounts of energy used in Australia in the foreseeable future. While all of the 30 million tonnes of brown coal mined are consumed in Australia, only 31 million tonnes of black coal (of the total 84 million tonnes produced) are consumed here. The remainder, mostly coking coal, is exported (principally to Japan) and contributes substantially to the 40% of Australian exports that is represented by minerals.

23.4.50 As coal tends to occur in more or less continuous seams conforming with the structures of enclosing sedimentary rocks, the activities of geologists are commonly directed, not so much to exploration in the sense used for metalliferous ores or petroleum, but to establishing properties which will determine whether mining will be feasible. These properties include the detailed attitude, thickness and number of seams, their structure, the presence of faults or other irregularities, the nature of roof rocks, and the quality of all coal present.

23.4.51 Geoscience work on coal is carried out by companies, the Australian Coal Industry Research Laboratories (ACIRL), CSIRO, the Joint Coal Board (NSW), the Queensland Coal Board, and by other State government bodies including both Geological Surveys and electricity authorities. There is little direct BMR work on coal although their regional and sedimentary basin studies are highly relevant. Most of the work by companies and government bodies is detailed mapping, usually based on intensive drilling in limited areas. As well as serving their immediate economic needs these studies often provide new insights into depositional processes and into the subsequent history of virtually unmetamorphosed sedimentary rocks.

23.4.52 The activities described above are supported by the research of a few individuals and small groups in the Universities of Sydney, NSW, Newcastle, Wollongong and New England, and in the NSW Institute of Technology. This research extends to fields such as coal petrology, sedimentology, mineralogy, seismic work, palaeobotany and the petrology of rocks associated with coal seams. Organisation of funding for research on coal is summarised in Figure 24.1 in Chapter 24 ('Mining and Mineral Processing').

23.4.53 The CSIRO Fuel Geoscience Unit conducts research into the origin, occurrence and assessment of coal of all types. This work includes a study of properties determined at the time of deposition, such as petrographic type and mineral content and also the changes in properties of coal resulting from increases in rank. The Unit is also concerned with the generation of gas in coal measure rocks while the CSIRO Divisions of Mineral Physics and Applied Geomechanics are using detailed geological mapping and statistical evaluation of data in the solution of problems encountered during coal mining.

Non-metalliferous deposits

23.4.54 In 1975-76, the value of non-metalliferous products of mining that were produced in Australia amounted to \$403million made up of construction materials 63%, precious stones 10%; salt 7%, limestone 7%, clays 4%; asbestos, gypsum, phosphate rock and silica 7%, and other materials about 2%. Table 23.1 shows that \$7million (or 1.7% of the total value of non-metalliferous production) was spent on exploration, reflecting the relative ease with which these materials can still be found in Australia.

23.4.55 Research on non-metalliferous materials is scattered over a diverse array of establishments including State Geological Surveys, State instrumentalities responsible for roads and construction, the quarrying industry and the Australian Road Research Board. It is estimated that the total expenditure does not exceed \$100,000.

23.4.56 The CSIRO Division of Mineralogy conducts research into non-metallic minerals such as clays and topaz. Some work of this kind is directed towards finding mineral deposits of, for example, particular clays which are not readily available in Australia. Work such as that on topaz is related to the assessment of a large resource of a potentially valuable refractory mineral.

Hydro-geology

23.4.57 Hydro-geology is the study of subsurface waters and related geologic aspects of surface water; 10% of all water used in Australia is groundwater. There is a close relationship between geology and the occurrence, distribution, hydraulic behaviour and chemical composition of groundwater. It is estimated that between 2.4% and 5.7% of the total R&D effort considered in this chapter is directed at hydro-geology (see Table 23.7); of this, 45% is contributed by State Mines Departments (WA, Qld, Tasmania), 26% from CSIRO, and the remainder from BMR, the Australian Atomic Energy Commission (AAEC) and the universities. Further information is presented in Chapter 38 ('Water Resources').

23.4.58 The programs of the State Mines Departments (except NSW) are predominantly directed at evaluation of groundwater resources although some studies of base metal geochemistry in deep bores and studies relating to effluent disposal have also been carried out. The NSW Water Resources Commission has a budget of \$2million for groundwater assessment of which \$1.2million is spent on drilling. An interesting new project, which involves hydro-fracturing to increase yields in bores, has just begun.

23.4.59 CSIRO's program is directed to hydro-geochemistry, in particular the distribution of trace elements in surface and underground water; dissolution and reprecipitation of uranium in draining systems has also been investigated. The main emphasis of BMR's program has been on the development of mathematical, computer-based models which simulate ground-water systems; these have been applied to studies of the Great Artesian Basin and to urban development areas in the ACT. The AAEC program is primarily directed at the study of ground-water, and surface water, transport using environmental and artificial isotopes. The effects of mining on the environment, including the groundwater regime, are also being studied in a number of areas. University investigations in this field have been into mechanisms of ground-water recharge, and limestone hydrology. The University of NSW is particularly active in hydro-geological research.

Resource assessment

23.4.60 The assessment of mineral resources, including petroleum and other energy minerals, is aimed at the compilation, estimation and evaluation of identified, and undiscovered mineral resources. Table 23.7 gives an estimate of the proportion of the total R&D expenditure in the geosciences that is directed to resource assessment, although varied interpretations of the term 'resource assessment' make this figure a very rough estimate.

APPLICATIONS OF GEOSCIENCE

Group 3: This group includes the categories of Engineering Geology and Geoscience Technology.

Engineering geology

23.4.61 Engineering geology is the application of geology to (mainly) civil and mining engineering. The application to mining engineering problems is dealt with elsewhere (Chapter 24). The application of engineering geology to civil engineering encompasses such fields as soil and rock mechanics, foundation and earth-structure interaction, hydro-geology and fluid-flow processes, ice mechanics, engineering geophysics, geo-pollution management, coastal and environmental studies, tunnel investigations and aggregate and resource evaluation.

23.4.62 Most engineering geologists in Australia are involved in studies for foundations for large buildings, environmental and aggregate evaluation, carrying out investigations for dam, bridge, road, railway and tunnel constructions and providing the basic geological data for the redevelopment of existing city complexes and proposed new cities.

23.4.63 In comparison with the total R&D effort considered in this chapter only a relatively small amount (less than 5%) is directed to engineering geology. The BMR, CSIRO and collective State Mines

Departments, and the AAEC, are largely concerned with tactical projects and problems, but some fundamental research is carried out. Although significant early research was undertaken by ANU and the Snowy Mountains Hydroelectric Authority, only the University of NSW and some colleges of advanced education are now actively involved in research. This is being carried out in the fields of fundamental rock mechanics, slope stability studies, dam site investigations and urban environmental studies particularly in relation to coastal processes, erosion and pollution.

Geoscience technology

23.4.64 Geoscience technology covers the development of equipment, techniques and methods required to solve the problems encountered in geoscience studies. Much of geoscience technology lies in the interface between geoscience studies and physics, chemistry, mathematics and engineering. Around 10% (see Table 23.7) of the total R&D covered in this chapter is directed to geoscience technology and, considering the non-industrial contribution, about 70% is done by CSIRO, BMR, and the State Mines Departments; the Australian Minerals Development Laboratories contribute about 20% and the universities probably provide the remaining 10%. The contribution made by industry is difficult to assess. Much of the geo-technical research is closely integrated with other activities and this makes it difficult to separate the research component in the work. Table 23.3 indicates a contribution from industry of about \$0.9million representing perhaps 20 man-years of effort.

23.4.65 In general, geophysical equipment used in Australia is based on overseas equipment and has been modified to suit Australian conditions. The BMR has always been active in the introduction, modification and building of equipment, and a few firms have developed equipment and equipment systems (especially for borehole logging and for airborne surveys); CSIRO is making a major contribution in the design of new surface and borehole methods.

23.4.66 Major projects in progress are:

- . Geochemical techniques to establish a guide to the occurrence of ore bodies at depth through the determination and interpretation of element distributions in surface and near surface materials. Geochemistry combined with satellite imagery has been used to define a prospective copper-bearing deposit in the Pilbara region.
- . Studies to improve the detection and interpretation of the associations that occur between geological features and economic mineralisation by the application of pattern-recognition techniques to geophysics, to geochemistry, to photo-geological interpretation, and geological data for the classification of rock formations, structural elements and the distribution of mineralisation. Satellite imagery is playing an increasing role in this area.

- . Studies at high resolution of seismic reflections from stratiform mineral deposits (both coal and base metals).
- . Development of equipment and techniques, including interpretation techniques, for borehole logging.
- . Application of airborne remote-sensing techniques to refine interpretation of the available Landsat imagery.
- . Extensive studies in research, development, interpretation and proving of magnetic, electric, seismic, and radiometric techniques and equipment for the detection of mineralisation at depth and for sensing in the marine environment.

23.4.67 Numerous advances have been made in the development of equipment and the application of computer techniques for data acquisition and interpretation. A special effort is being made at present to obtain uniform procedures for magnetic tape recording of geophysical information. The development by CSIRO of 'Sirotem', an instrument to detect mineralisation buried under thick overburden, is important for mineral exploration in tropical and arid environments.

23.4.68 The construction of the Australian Earth Science data base (AESIS) is another important development. AESIS is actively supported by the Commonwealth Government, State governments and industry. It is a register of current unpublished government and company reports on earth sciences. However, the information in this data base has not been extended backwards to cover literature available before the data base was started.

ANTARCTIC GEOSCIENCE RESEARCH

23.4.69 Australia's program of scientific research in Antarctica is drawn together through the Australian National Antarctic Research Expedition (ANARE) which is organised and supported by the Antarctic Division of the Department of Science.

23.4.70 Geological and geophysical research has been a major component of the ANARE program since its inception in 1948. Most of this research has been undertaken by BMR, with a minor, but significant, university component. Over the last decade, up to six BMR geoscientists have taken part in the ANARE field program each summer along with some university groups mainly from the University of Adelaide. The aim of the geoscience program in Antarctica is to elucidate the geological composition, structure and evolution of the Australian Antarctic Territory (AAT), and its relation to Antarctica as a whole. Most of the Australian effort has been devoted to the mainland. Knowledge of the geology and geophysics of the ocean floor surrounding Antarctica is therefore relatively limited.

23.4.71 Since 1961, after the early reconnaissance surveys had been completed, geological research has been within the framework of a 1:250,000 mapping program. To date fifteen maps have been published and work is underway on a further fifteen. Work is currently focussed on Enderby Land at the western end of AAT. The university-based geological research has concentrated on detailed studies of small but important areas and on geochronological studies. Geophysical research in Antarctica has been almost exclusively that performed by BMR. Seismic and magnetic observatories constantly manned by BMR officers were established on Macquarie Island in 1950, at Mawson in 1955, and at Wilkes in 1959 (closed 1967). Magnetic recording and calibrating equipment operates at both Davis and Casey stations. Magnetic and gravity surveys have been undertaken over the last few years as well as seismic investigations to determine ice thickness. In 1977 an experimental program of airborne magnetometer profiling began in conjunction with glaciologists' ice thickness measurements using radar.

NOTES AND REFERENCES

1. The scale of a map is expressed as the ratio of the unit of distance on the map to the equivalent distance represented on the ground. Thus a scale of 1 cm on a map equals 1 km (100,000 cms) on the ground is expressed as the ratio 1:100,000. The map scale is then said to be 1:100,000. A map drawn at the scale of say 1:10,000 is said to be drawn at a larger scale to one drawn at the scale of 1:100,000 because 1:10,000 is a larger number than 1:100,000. This causes confusion because a map drawn at 1:10,000 scale of the same physical dimensions as one drawn at 1:100,000 scale, represents a smaller area (23.1.3 and 23.4.10).
2. The Crust of the earth comprises all that material above the first major density discontinuity in the earth (the Mohorovicic Discontinuity). In continental areas the crust is 30-50 km thick whereas in oceanic areas it is about 5 km thick. The Mantle of the earth extends from the base of the crust to the Core of the earth and is about 3000 km thick (23.4.8).
3. Project SCORE (Survey and Comparisons of Research Expenditures), Research and Development in Australia 1973-74. 2 vols., Vol. 1, 153 pp., Vol. 2, 145 pp. Australian Government Publishing Service, Canberra, 1977.

OECD DEFINITIONS OF R&D

Definitions of Research and Development as used by the OECD - Extracts from 'The Measurement of Scientific and Technical Activities Frascati Manual', OECD, Paris, 1976, pp.26-27

In certain cases the theoretical criteria for distinguishing between R&D-related activities are particularly difficult to apply and national practice may vary. Space exploration, and mining and prospecting, are two areas where large amounts of resources are involved and so any such variations will have important effects on the international comparability of the resulting R&D data. For this reason the following conventions apply for international comparisons.

(a) Space exploration:

Routine space exploration should be included in R&D.

(b) Mining and prospecting:

There is often a linguistic confusion between 'research' for new or substantially improved resources (food, energy, etc.) and the 'search' for existing reserves of (known) natural resources which complicates the issue when discussing the distinction between R&D and surveying and prospecting.

In theory, in order to establish accurate R&D data, the following activities should be identified, measured and summed:

- . the development of new surveying methods and techniques,
- . surveying undertaken as an integral part of a research project on geological phenomena;
- . research on geological phenomena per se undertaken as a subsidiary part of surveying and prospecting programs.

In practice, the third of these presents a number of problems. It is difficult to frame a precise definition which would be meaningful for respondents to national surveys. The sums involved are probably relatively small in practice, but a misreading by respondents might lead to large amounts of 'search' resources being counted as R&D.

For this reason, for the present and by convention, only the following activities should be included in R&D:

- . The development of new or substantially improved methods and equipment for data acquisition and for the processing and study of the data collected, and for the interpretation of these data.

Surveying undertaken as an integral part of a research project on geological phenomena per se including data acquisition, processing and interpretation undertaken for primarily scientific purposes. By convention, shallow stratigraphic bore holes are included in this heading.

It follows that the surveying and prospecting activities of commercial companies will be almost entirely excluded from R&D. For example, the sinking of exploratory oil wells and other exploration whose aim is to decide a question such as the evaluation of the resources of a deposit should be considered as general purpose data-collection.

APPENDIX 23.2

AUSTRALIAN COUNCILS, STANDING COMMITTEES, CONFERENCES, SYMPOSIA RELEVANT TO EARTH SCIENCES

Australian Minerals and Energy Council (AMEC). Membership - Minister for Trade and Resources, Minister for National Development and State Ministers concerned with minerals and energy. Meetings are held once or twice annually.

Advisory Committee of AMEC. Membership - Permanent Heads of Departments whose Ministers comprise AMEC. Meetings are held once or twice annually.

Chief Government Geologists Conference (CGGC). Membership - Director of BMR and Chief Geologists of State Geological Surveys. Meetings - annual. Purpose - to exchange information and to discuss programs and related problems. This Conference reports to the Advisory Committee of AMEC.

Conference of Chief Draftsmen State Mines Departments and BMR. Membership - Chief Draftsmen of BMR and State Geological Surveys. Meetings - annual. Purpose - to exchange information and to discuss programs and related problems. This Conference reports to the CGGC.

NSW Committee for Co-ordination of Government Geological Programs. Membership - representatives of Geological Survey of NSW, BMR, CSIRO, Department of Main Roads, Electricity Commission of NSW, Joint Coal Board, Water Resources Commission, Metropolitan Water Sewerage and Drainage Board, Australian Museum. Meetings - six monthly. Purpose - to exchange information and discuss programs and related problems.

Technical Committee on Oceanography. Membership - representatives of BMR, CSIRO, universities, museums, Departments of Defence, Navy, Science, Transport. Meetings - irregular. Purpose - to allocate ship-time to competing interests.

Consortium for Ocean Geosciences of the Australian Universities (COGS). Membership - Academic staff from 16 university geoscience departments. Meetings - irregular. Purpose - to co-ordinate and further the interests of marine geoscience in Australia.

State Mining Engineers Conference. Membership - representatives of BMR, State Mines Departments, New Zealand. Meetings - annual.

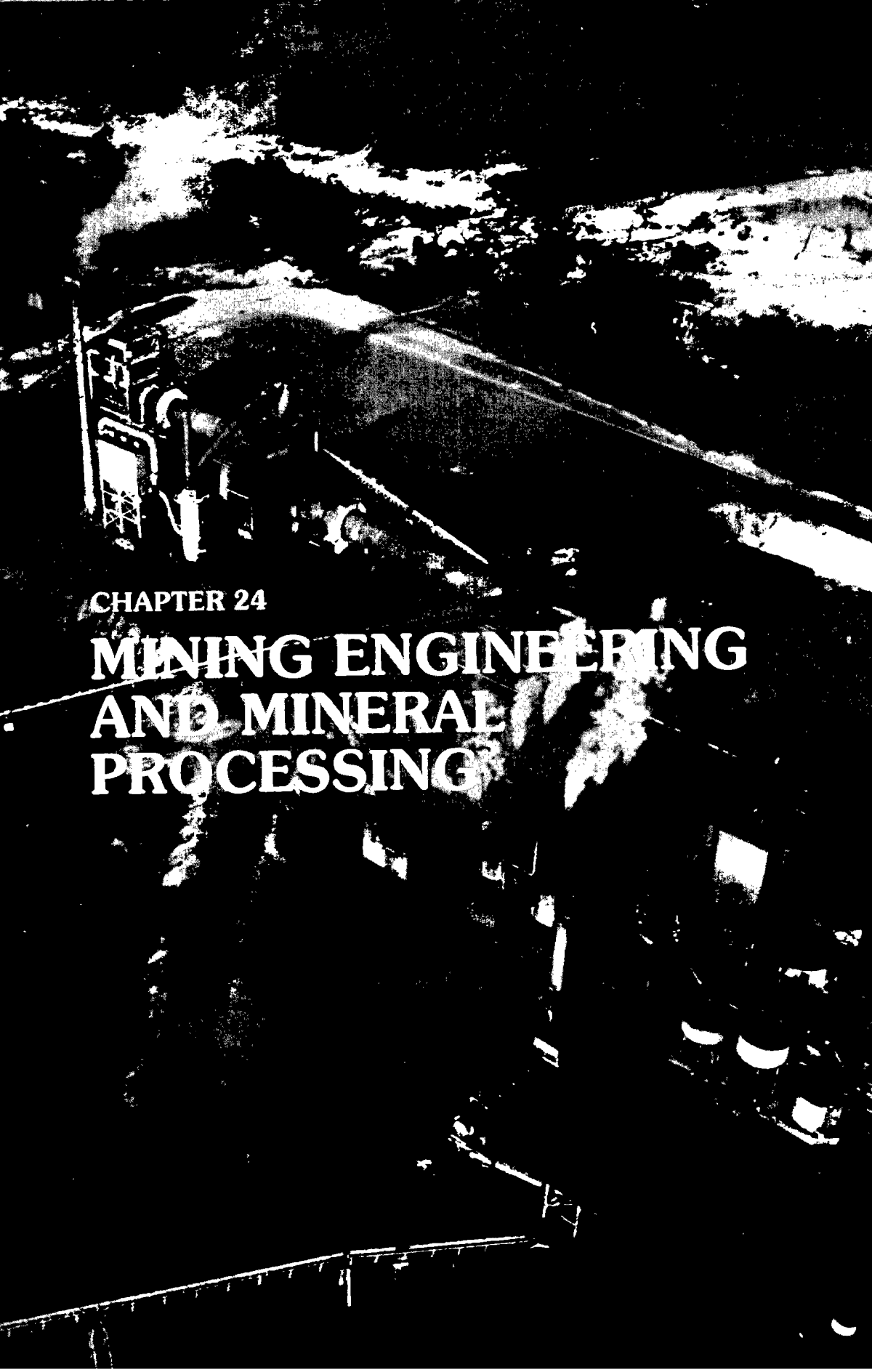
Australian National Committee World Petroleum Congresses. Membership - representatives of BMR, a representative of the State Mines Departments, Institute of Petroleum, Petroleum Information Bureau. Australian Petroleum Exploration Association, industry.

National Committee on Earthquake Engineering. Membership - representatives of BMR, other Government Departments, insurance companies, and individuals.

Baas Beeking Geobiological Research Laboratory Policy Committee. Membership - representatives of BMR, CSIRO, AMIRA. Meetings - irregular.

Australian Academy of Science Committees

- . National Committee for Antarctic Research;
- . National Committee for Geochemistry, Cosmochemistry and Mineralogy;
- . National Committee for Geodesy and Geophysics;
- . National Committee for Crystallography;
- . National Committee for the International Geodynamics Project;
- . National Committee for the International Geological Correlation Program;
- . National Committee for Hydrology;
- . National Committee for Oceanic Research;
- . National Committee for Quaternary Research;
- . Pacific Science Committee.



CHAPTER 24

MINING ENGINEERING AND MINERAL PROCESSING

Photograph: Synthetic rutile is produced in this ilmenite ore-beneficiation plant by a direct reduction process developed in Australia by Western Titanium Ltd. The process originated in the Western Australian Government Chemical Laboratories and CSIRO Mineral Research Laboratories are involved with Western Titanium in optimising the operating conditions of the process. The plant is the first of its kind in the world and is situated at Capel, 200 km south of Perth, WA.
(Photograph courtesy Western Titanium Ltd).

CHAPTER 24

MINING ENGINEERING AND MINERAL PROCESSING

24.1 INTRODUCTION

DEFINITION OF AREA COVERED

24.1.1 The mining industry is made up of three interacting elements : exploration, mining, and processing. Major R&D programs for mining engineering and mineral processing are reported. R&D projects covering exploration are reported in Chapter 23 'Earth'. Projects which may be pertinent to mining and processing may be found in other chapters, in particular 'Metal Products and Machinery', 'Energy', 'Transport' and 'Environment'.

BACKGROUND

24.1.2 Australia is a net exporter of coal and other minerals with mining operations widely spread geographically, often in what are regarded as remote areas, such as the iron-ore mines of the Pilbara in Western Australia. However, quarrying, the mining of materials for the construction industry, must be conducted near population centres.

24.1.3 There are several unique aspects about mining when compared with other industries. Every mineral deposit (ore body) presents its own particular problems, which may be concerned with the delineation of the reserve, the method of mining, or difficulties in processing. Moreover, the purpose of mining and processing is to convert the mineral deposit into an asset, albeit with a finite life. If therefore a mining company wishes to survive it must be involved in the seeking of further mineral deposits. Exploration may take place within the immediate area of existing operations as well as in new areas.

24.1.4 Mineral deposits are in most cases the property of the 'State'. The effect is that a mining company (or person) must obtain some type of approval, usually a licence, from a government authority before exploring or mining in a particular area. A royalty is often paid on the minerals mined or extracted. Hence the 'State' (Commonwealth and State Governments) is very much involved in the development and administration of the industry.

24.1.5 Mining and processing, particularly open-cut mining and oil and gas extraction, tend to be capital-intensive. Underground mining is

somewhat more labour-intensive than open pit mining, but any sizeable underground mine still requires large amounts of capital for development. It is for this reason that the mining industry tends to be dominated by large organisations, but mining for gemstones is still very much the prerogative of the small miner.

24.1.6 Mining itself is largely a non-competitive activity but there is competition in the mining industry in the search for new deposits (exploration) and in the negotiation and maintenance of sales contracts. Much of the R&D in the industry is accepted as being non-confidential and a considerable amount is done co-operatively through industry organisations, in government organisations, and at tertiary education institutions. The results of this type of R&D are usually made available to the whole of the industry.

24.1.7 The main effort in R&D in the mining industry in Australia is in the coal and metalliferous sectors. Much of the R&D for metalliferous mining can be directly applied to the coal and the non-metalliferous mining sectors. The differences are principally in the nature of the products sought and in the methods of processing and utilisation. Apart from coal, a large portion of non-metalliferous mining is for construction purposes, that is the quarrying of rock for aggregate and the mining of sand and gravel.

24.1.8 The oil and natural gas industry is, by comparison with metalliferous mining and also with coal mining, a relatively young industry in Australia. The technology required for its development has been acquired from overseas and in consequence most of the R&D is done overseas.

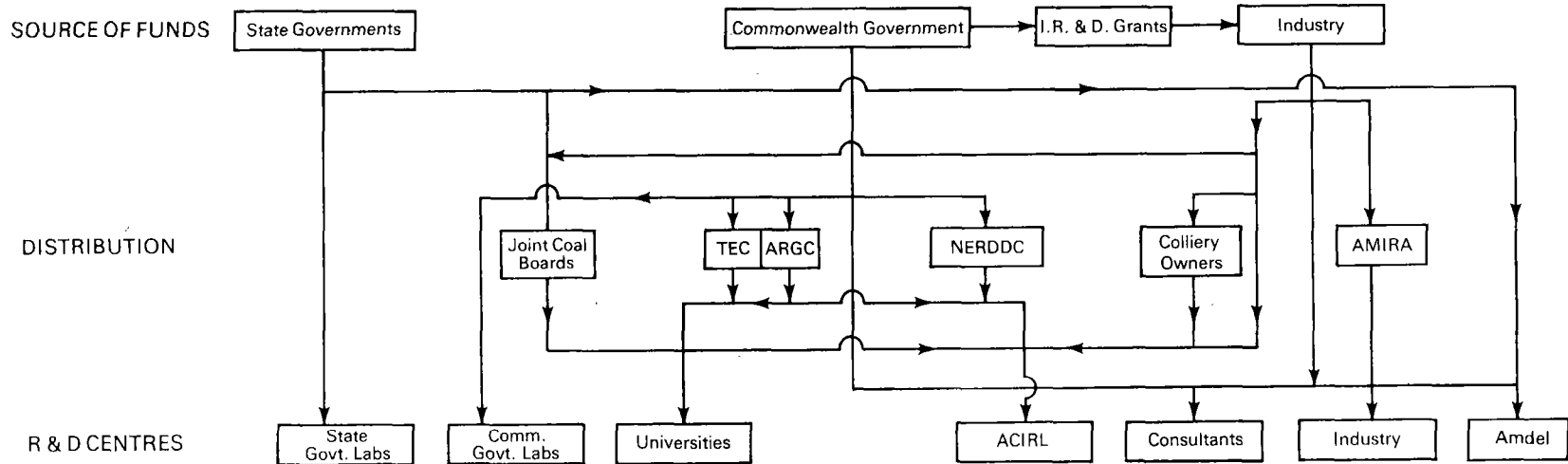
24.1.9 At the present time most R&D associated with uranium mining and processing is concerned with effects on health and the environment. Although in general the problems in the mining of uranium are the same as for metalliferous mining, there are some unique aspects due to the radioactivity of the ores.

24.2 ORGANISATION, POLICIES AND FUNDING

24.2.1 The relationship, in the organisation and funding of mining and processing R&D by both industry and government (Commonwealth and State), is shown in Figure 24.1.

24.2.2 Industry organises R&D in several ways. Some is carried out in company laboratories, mines and plants where the emphasis is on R&D pertinent to the particular situation. In addition, companies often use government research organisations such as the CSIRO, consultants or consultancy organisations, to handle specific R&D projects which they themselves may not be equipped to handle. Companies also sponsor co-operative R&D through such organisations as the Australian Mineral Industries Research Association (AMIRA) and the Australian Coal Association.

FIGURE 24.1
RELATIONSHIP OF SOURCE OF FUNDS, DISTRIBUTION
AND R&D CENTRES



Colliery Owners — Covers various Associations which make up Australian Coal Association.
Tertiary Education Commission (TEC), Australian Research Grants
Committee (ARGC), National Energy Research, Development and Demonstration
Council (NERDDC), Australian Mineral Industries Research Assoc. Ltd. (AMIRA), Australian
Mineral Development Laboratories (Amdel), Australian Coal Industry
Research Laboratories (ACIRL).

Such organisations do not carry out the R&D but arrange contracts for it to be done by such organisations as the Australian Mineral Development Laboratories (AMDEL), Australian Coal Industry Research Laboratories (ACIRL), CSIRO, universities, or those, including overseas establishments, with facilities appropriate for the project.

24.2.3 AMIRA is an industry-based research association with a membership of 44 companies, which organises co-operative R&D, assists in establishing R&D priorities both for AMIRA and the organisations with which it is associated, and which co-ordinates research activities.

24.2.4 The liaisons which have developed throughout industry due to the work of AMIRA have helped to minimise duplication of R&D effort. AMIRA study groups and sub-committees have assisted in bringing into focus areas where R&D effort is needed. Since 1959, AMIRA has arranged the funding of 78 new projects or extensions of projects. In recent years up to 20 projects covering exploration, mining and processing have been running concurrently, with an annual cash flow of about \$0.5million. The results of non-confidential research are published annually.

24.2.5 Representatives of the industry meet regularly through AMIRA with staff of the CSIRO Minerals Research Laboratories to review the R&D programs of the Laboratories. Industry personnel have worked on short-term projects with CSIRO personnel. This interchange of personnel in both directions is an accepted policy for both CSIRO and industry.

24.2.6 AMIRA convened a meeting, early in 1978, of representatives of all organisations interested in minerals R&D. The objective was to improve communication between research groups and between the industry, research groups and consultants.

24.2.7 In general, the industry finances its own R&D programs, although some government assistance has been received through project grants from the Australian Industrial Research and Development Incentives Board (AIRDIB).

24.2.8 The Commonwealth Government's main effort in R&D for mining and mineral processing is through the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and to a much lesser extent, through the Bureau of Mineral Resources (BMR), and the Australian Atomic Energy Commission (AAEC). The policy of all three organisations has been to carry out work in areas where a broad application is possible rather than to work on problems peculiar to a particular situation, although there have been exceptions to this. These Commonwealth Government research establishments are funded by the Treasury, with some contribution from industry for certain projects.

24.2.9 The exploration, mining and processing R&D of the State Governments is organised through their respective Mines Departments. These have the responsibility of making and enforcing mining legislation for their particular State. R&D is mostly concerned with assessing mineral potential, and with safety and environmental matters; it is funded by the respective State Treasuries. R&D in universities is financed with government funds, and by grants from industry for some specific projects.

24.2.10 Until June 1977, the Commonwealth Government contributed to a research trust fund for coal that was administered by the National Coal Research Advisory Committee (NCRAC). The functions of NCRAC were to review and recommend which R&D programs for coal should be supported and the extent of that support. ACIRL was the chief beneficiary although some funds also went into universities. The Joint Coal Board (NSW) and the Queensland Coal Board have provided funds for specific R&D programs, mostly with ACIRL.

24.3 DESCRIPTION OF R&D ESTABLISHMENTS

COMMONWEALTH GOVERNMENT

CSIRO Division of Applied Geomechanics

24.3.1 This Division is concerned with the properties of soils and rocks in relation to the design of civil and mining engineering structures. The laboratories are at Syndal, Victoria. Within the broad policy set by the Executive, the direction of research resides with the Chief of the Division. Research reviews (initiated by the Executive) are held approximately biennially. Application oriented reviews, held in conjunction with industry personnel are more frequent. Staff positions and funds are allocated by the Executive from Treasury sources. Contributory funds from industry are used to assist work on specific projects. The annual budget for 1977-78 is \$2million. There are 39 professional and 58 supporting staff.

CSIRO Minerals Research Laboratories (MRL)

24.3.2 MRL is comprised of five divisions and one independent unit. These are the Divisions of Chemical Engineering (Clayton, Victoria), Mineral Chemistry (Port Melbourne, Victoria), Process Technology (North Ryde, New South Wales and Port Melbourne, Victoria), Mineral Physics (North Ryde, NSW), Mineralogy (Perth, Western Australia and North Ryde, NSW) and the Fuel Geoscience Unit (North Ryde, NSW).

The Director of MRL is responsible to the CSIRO Executive for the definition, and the allocation of resources to, the programs of research undertaken by the above units. His responsibilities include the formulation of a CSIRO minerals research program and the control and disbursement of minerals research finance. Co-ordinated program planning in MRL takes place via regular meetings between the Director, Chiefs of Divisions, and research staff. There are frequent meetings of study groups from CSIRO and AMIRA to review research objectives and the progress that has been made. Staff and funds are provided from the annual Treasury appropriation to CSIRO. Additional staff and funds are provided by outside contributors to assist with the conduct of collaborative research ventures which relate to MRL programs. The budget for 1977-78 is \$10.5million. The total staff is 530, of which 256 are professionals.

24.3.3 Other Divisions of the CSIRO such as Materials Science and Mechanical Engineering do, from time to time, contribute their specialist skills to mining R&D. The Bureau of Mineral Resources (BMR), described in Chapter 23 ('Earth'), does some mining and processing R&D.

24.3.4 The Australian Atomic Energy Commission (AAEC) is involved in various aspects of R&D into mining and mineral processing. A small part of the effort is on uranium processing. A larger part is on research, development and demonstration of nuclear techniques of analysis applied to the mineral industry. The AAEC is also involved in research into the health and environmental aspects of mining uranium ores; this work is described in Chapter 36 ('Environment').

STATE GOVERNMENT

Department of Mines, NSW

24.3.5 R&D is undertaken by the following branches of the Department:

- . Mines Inspection;
- . Coalfields;
- . Geological Survey of NSW;
- . Londonderry Centre;
- . Chemical Laboratory.

24.3.6 The Department's program and budgets are prepared annually but there are monthly reports and reviews, together with a detailed review every six months. All staff are State public servants and are recruited within the policies of the NSW government of the day. Funds are provided by the State Treasury.

24.3.7 The Chemical Laboratory is situated at Lidcombe (NSW). The Department's engineering testing and research facilities are housed at the Londonderry Centre near Penrith (NSW). These facilities are used for a wide range of R&D related to metalliferous, coal and non-metallic mining.

Department of Mines, Tasmania

24.3.8 The Metallurgical Laboratory at Launceston specialises in ore dressing investigations that are relevant to mineral occurrences in the State; these can extend to the pilot plant scale. They may also be carried through to processing, using hydrometallurgy or pyrometallurgy, but such research is confined to the bench scale. The Laboratory is under the control of the Chief Chemist and Metallurgist who reports to the Director of Mines. All funds are from Departmental sources although fees are charged for certain classes of work.

Mines Department, Western Australia

24.3.9 Mineral investigations are handled by the Engineering Chemistry Division which forms part of the Government Chemical Laboratories, Perth. The Chief of the Division, who is responsible to the Director of the Laboratories, directs research work which will aid the development and utilisation of the State's mineral resources. Although the emphasis is generally on applied studies, and may, on occasion, involve little more than evaluating the applicability of proven processes to the treatment of local ores, the Division has acquired a sound reputation as a result of its work on projects of longer-term significance.

TERTIARY EDUCATION INSTITUTIONS

Department of Mining and Metallurgical Engineering, University of Queensland

24.3.10 Most mining research is done at the university's experimental mine, a disused silver/lead mine, located some 5 km from the university, at Indooroopilly.

24.3.11 Also located at this site is the Department's Julius Kruttschnitt Mineral Research Centre. Its main expertise is in the control of plant for mineral processing. It is the largest academic centre in the country devoted to post-graduate research and training in the broad field of mining engineering and mineral processing. The Director of the Centre reports to a Policy and Planning Committee which is chaired by the Chairman of the University of Queensland Research Committee. Both the Committee and the Director receive advice from the Centre's Technical Advisory Committee.

School of Mining Engineering, University of NSW

24.3.12 The school is controlled by the Head with some supervision from special university committees. There are 14 postgraduate students working in the general areas of mining economics and minerals engineering.

Mineral Chemistry Research Unit, Murdoch University

24.3.13 This is a semi-autonomous unit within the School of Mathematical and Physical Sciences. It is responsible for research on extractive metallurgy and mineral chemistry that is relevant to the Australian mineral industry, and is controlled by a Director who receives advice from the governing body (which is a Senate sub-committee) as well as from State departments and from industry.

Department of Mining and Metallurgy, University of Melbourne

24.3.14 The department is under the control of a Chairman. Postgraduate research in both mining and mineral processing is in progress; some of this research is sponsored by industry.

24.3.15 It should be noted that there are many other centres in universities and institutes of technology which are engaged in the training of students for, or in research of interest to, the mining industry e.g. the Department of Materials and Mining Engineering at the University of Sydney. Although not identified here, some of the work of these research teams is referred to in later sections.

CONSULTANTS

Australian Coal Industry Research Laboratories Limited (ACIRL)

24.3.16 ACIRL was incorporated as a non-profit company in 1965 following a report of the Coal Utilisation Research Advisory Committee to the Minister for National Development in 1962. It is a company limited by guarantee and not having a share capital. The Board of Management is made up of representatives of industry, the Commonwealth Government, and State Governments. Administration of ACIRL rests with a Director.

24.3.17 ACIRL has its own well established, experimental, research facilities located in five laboratories. These laboratories are concerned with coal mining, coal preparation and distribution, and coal utilisation. The central laboratory and headquarters is at North Ryde, NSW; the other four are in the coalfield areas of New South Wales (Bellambi and Maitland) and Queensland (Ipswich and Rockhampton). Its staff of 35 professionals conducts confidential research on behalf of individual companies and non-confidential research funded by the Commonwealth Government, the Australian Coal Association, the Joint Coal Board, the Queensland Coal Board and various companies. Results of non-confidential research are published and widely circulated.

Australian Mineral Development Laboratories (Amdel)

24.3.18 Amdel is constituted as a Statutory Body under an Act of the South Australian Parliament, and is jointly sponsored by the Commonwealth Government, the South Australian Government and AMIRA. Amdel provides technical, engineering, consulting, development and pilot plant services to industry and government in Australia and overseas. Its staff of 52 professionals operates under a Managing Director as a client-oriented, financially viable corporation with the required flexibility and capacity to adapt to changes in demand for its services.

24.3.19 Because a great deal of its work is conducted under contract, Amdel is at a disadvantage in reporting publicly its wide range of investigations; however, the scientific content of some of its research is disseminated through regular editions of the Amdel Bulletin. In the category of mineral processing it has 11 professionals working on the beneficiation of ferrous and non-ferrous minerals. There are three professionals each in the areas of pyrometallurgy, general techniques and non-metallic minerals, and two professionals in hydrometallurgy.

INDUSTRY

24.3.20 The larger companies maintain their own R&D sections with laboratories which generally provide facilities for geological, mining and metallurgical research. Mining R&D within the companies tends to be experimental, and much of this work is carried out at the mine site.

Abminco NL

24.3.21 The company conducts research for the development and improvement of existing concentrating processes at the Cleveland and Aberfoyle mines in Tasmania, and also conducts special projects such as its collaborative study of matte fuming (a technique that replaces flotation) with CSIRO. The company is a subsidiary of the Canadian-owned Cominco Ltd.

Associated Minerals Consolidated Ltd

24.3.22 R&D for all the company's interests - including those of the wholly owned subsidiary, Western Titanium Ltd - are centred at Southport, Queensland, where a technical development group is responsible to the Managing Director. The group investigates several development projects which in general relate to the improvements of existing processes.

Australian Consolidated Industries Ltd

24.3.23 The ACI Technical Centre at Waterloo is the leading laboratory in the category of non-metallic mineral production. Many of its 60 professional staff are studying the nature, and possible beneficiation, of Australian raw materials (see 24.5.22).

Broken Hill Proprietary Company Limited (BHP)

24.3.24 BHP employs 196 professionals in its R&D programs; the budget is in excess of \$10million. In total, BHP conducts 36 major programs which relate to this total ASTEC Report; almost one-half of the total effort is devoted to research on mining and mineral processing.

Cobar Mines Ltd

24.3.25 The company is a wholly-owned subsidiary of Broken Hill South Ltd. The number of the company's research staff is comparatively small and the program of work is largely directed towards the medium or long term.

Conzinc Riotinto of Australia (CRA)

24.3.26 CRA has one of the largest research components of the Australian-based mining companies. Its budget for 1977 exceeded \$3million and there were 58 professional research workers (these figures do not include the research activities of CRA's subsidiaries, Hamersley Iron Pty Ltd, Bougainville Copper and Comalco Limited). In addition to major programs which operate on budgets of the order of \$200,000 the company supports numerous smaller programs in many areas related to exploration, mining, mineral processing and environment.

Broken Hill Associated Smelters Pty Ltd

24.3.27 The company is 70% owned by Australian Mining and Smelting Ltd, a CRA subsidiary, and North Broken Hill Ltd. It is autonomous and subject to the authority of its Board which approves capital and project expenditure for research. Its professional staff of 18 has been included in the total CRA professionals.

Comalco Ltd

24.3.28 Although the research laboratory, with a professional strength of 22, is the largest of any concerned with aluminium in Australia, the company considers that the level of research effort would need to be trebled in order to meet the technical challenges presented by problems related to extraction of alumina, production of anode carbon, prevention of corrosion, improved recycling and metal-forming technology.

Hamersley Iron Pty Ltd

24.3.29 The company's research is designed to improve the efficiency of existing operations and to provide knowledge concerning the properties of ores from new sources. It conducts its own research in the central development laboratories at Dampier and also commissions work to outside organisations. The company's laboratories are responsible to the the Chief Metallurgist who reports to the Technical Services Department.

Sulphide Corporation Pty Ltd

24.3.30 Sulphide Corporation is a wholly-owned subsidiary of Australian Mining and Smelting (AMS) Ltd, itself a CRA subsidiary. The company is closely involved with the two research committees which were set up within AMS to improve long term planning capability. One of these committees is concerned with research into the uses of zinc and lead and the other with the mining and smelting of lead and zinc concentrates. The professional staff (17) has been included in the CRA total.

CSR Ltd

24.3.31 The CSR Research Laboratories, which are the central laboratories for CSR Ltd, employ 40 graduate workers and have an annual budget of about \$3million; about 12 are engaged on minerals R&D. The Laboratories Manager reports to the Director of Research who is responsible for work for the three major Divisions of CSR and also for the conduct of research devoted to potential new business activities. Re-organisation currently under way is devolving direct responsibility for R&D to the three CSR divisions.

Electrolytic Zinc Company of Australasia Ltd

24.3.32 The company's R&D activities, which involve up to 50 professionals, are located on the Risdon (Tasmania) site and in other areas of company operations. A tradition of long-range research exists.

ICI Australia Ltd

24.3.33 This group of companies, with some 400 professionals committed to R&D and a budget of the order of \$16million, provides the largest complex of industrial research in Australia. Approximately half the staff is located in two major laboratories. The proportion of research strength committed to mineral processing and mining (especially in the field of explosives) varies, but currently there are 36 professionals working in this area.

MIM Holdings Ltd

24.3.34 The Company has a long and continuing record of research in geology, mining, processing and smelting. The number of professionals at Mt Isa varies from 50 to 60. The company has been closely involved with the development of the Julius Kruttschnitt Research Centre (see 24.3.11).

Mineral Deposits Ltd

24.3.35 This company's Research and Engineering Division has extensive pilot plant and laboratory facilities devoted to the development of new technology in the field of gravity separation and the application of that technology to the minerals industry. Since 1973 the company has specialised in mathematical modelling techniques which can produce a balanced flow-sheet for the production of concentrates from a suite of minerals.

Readings of Lismore Pty Ltd

24.3.36 This unique, private company, wholly owned by the members of the Reading family, commenced as a small engineering service unit in 1946. It specialised in the modification of processing equipment for the mineral sands industry, and pioneered the development of magnetic separators specifically designed for the Australian market. The work of the Company's Minerals Research Laboratory, which was established in 1971, has led to the production of equipment which now meets the demands of an overseas market that is three times larger than the local.

24.4 DESCRIPTION OF MAJOR R&D PROGRAMS (MINING ENGINEERING)

GEOMECHANICS (GROUND SUPPORT)

24.4.1 An important centre for research into the problems of supporting the ground in the neighborhood of a mining operation, is located within the Division of Applied Geomechanics, CSIRO. Much of the work of this group is done in association with mining companies which share the costs. The work involves both laboratory and field studies. An important project

funded by the CSIRO and a coal producer in the Bowen Basin in Queensland is concerned with the instability of high walls and spoil piles in a strip-mining operation. The aim is to establish the causes, to define methods of predicting possible instability, to develop control and remedial measures, and to outline a procedure for the application of the results to other areas. Techniques for the monitoring of mass movements have been developed. After the mechanisms of failures and their control are established, a process for undertaking deep stripping operations may be possible. Of a total staff of 15, 7 are professionals.

24.4.2 A major project, funded jointly by AMIRA and CSIRO, is the support and stabilisation of stopes. The aim is to increase mining efficiency consistent with safety, by determining the geomechanical principles involved in maintaining, for as long as required for mining purposes, the integrity of underground openings. Five aspects are being studied:

- . design requirements for cemented sand and rock fill;
- . pre-placed mechanical support;
- . open stope design;
- . the use of post pillars; and
- . stress monitoring and crown pillar design.

Field work is concentrated at the mining sites of the four major sponsors of the project. A field laboratory has been established at Cobar. The project is well advanced. Of a total staff of 25, 11 are professionally qualified. The mine staff also provide a considerable amount of support at the field work sites.

24.4.3 A smaller project, involving the CSIRO, is the development of a mathematical model for the analysis of superincumbent stress caused by underground mining. A research project, to advance this relatively new technique by the inclusion of non-homogenous materials and structural features in the models, is under examination. The advantage that this method has over the finite element and finite difference methods is that only the boundary surfaces, not the entire volume, need to be defined for analysis. Two professional workers are involved.

24.4.4 ACIRL has a project in progress for the development of mining systems to extract coal seams of 6 metres or more in thickness at depths of cover of about 400 metres. In addition to facilities for mathematical analysis, hydraulic test rigs are available for studying the behaviour of scaled models. Data from actual mining situations are being compared with that derived mathematically. It is planned to establish full-scale, underground operations at a selected test site in Queensland, in order to test the predictions from laboratory work.

24.4.5 MIM Holdings Ltd has seven professional engineers and geologists working on geomechanical (rock mechanics) projects. These are part of an on-going program to increase the knowledge of rock behaviour associated

with underground mining, the aim being to make future mining more predictable; this will lead to an improvement in safety and efficiency. Close liaison is maintained with the CSIRO Division of Applied Geomechanics and with certain departments of the University of Queensland and of James Cook University of North Queensland.

24.4.6 A project which involves one professional and one part-time consultant at Mt Isa monitors the noise in rocks. This project covers test work associated with the installation of a microseismic, monitoring system in a crown pillar area of the lead section of the mine. The installation is based on previous work done in South Africa and in deep lead mines in the USA. The objective is to locate the source of rock noise which is caused by the build-up of stress within the rock. As knowledge of the mine situation increases, there is a possibility that techniques for prediction of the growth of dangerous stresses can be developed with a view to increasing mine safety. Similar work of this nature has been done at mines in Cobar and Broken Hill.

24.4.7 The Department of Mines, NSW, has three professional and two technical officers engaged in studying surface subsidence resulting from the extraction of coal. The aim of this project is to obtain sufficient information to be able to calculate the effects of subsidence under various geological conditions and methods of extraction. Field teams have been established to monitor surface movements by direct measurement in undermined areas. To date, the position and magnitude of the maximum subsidence can be determined together with the general shape of the subsidence trough.

24.4.8 In another project of the NSW Mines Department, sub-surface subsidence in coal mines is being examined. This project is designed to determine the variation and mechanics of vertical movement between surface and seam following full extraction of coal measures. After consultation with other sections of the Department and the AAEC, a technique to measure movement around boreholes has been developed but this is yet to be tested on site.

24.4.9 BHP has a rock mechanics and strata control group at Wollongong. This comprises seven professionals working on a variety of projects associated with coal mining in co-operation with the BHP Central Research Laboratories and the CSIRO Division of Applied Geomechanics.

24.4.10 At MIM Holdings Ltd, two professional engineers supported by part-time university and CSIRO consultants are engaged on a mine-fill research project which is concerned with the assessment of the stability of fill and the optimisation of the cost and strength of fill in order to reduce the high cost of filling operations. Current work involves the assessment of fill as an engineering material to determine the strength and stability underground as pillars are recovered. This is done by monitoring the performance of fill as mining progresses and the development of mathematical techniques to analyse complex engineering aspects. Investigations are under way to reduce costs by the addition of aggregate to hydraulic, and cemented hydraulic fill.

24.4.11 Two research students at the University of NSW are engaged on a project to evaluate mine waste, rock and tailings as support material in metalliferous mine stoping operations. MIM Holdings Ltd provides financial support for this work.

24.4.12 At Zinc Corporation, Broken Hill, two professional staff are engaged on a project to develop a mine, back-fill material, which is stable when exposed over large vertical intervals, and which will permit the use of mass extraction methods during the secondary recovery of ore pillars in the mines at Broken Hill.

24.4.13 The CSIRO Division of Mineral Chemistry has two professional staff working on problems arising in the use of self-cementing mine fill, and on problems associated with the combustibility of sulphides in mines.

24.4.14 Three professional research workers in the CSIRO Division of Mineral Physics are attempting to relate the collapse of coal mine roofs to geological faults and surface features that are revealed in photographs taken from aeroplanes or satellites. This work is being correlated with that being done by the CSIRO Division of Applied Geomechanics.

24.4.15 Two research students at the School of Mining Engineering, University of NSW, are conducting investigations into the control of strata pressure for improving the access to, and the recovery of, coal at depth.

MINE DESIGN

24.4.16 The CSIRO Division of Applied Geomechanics has three professional officers supported by three other staff engaged in developing methods for the design of mines using geomechanical data obtained during the exploration phase. They aim to define mining conditions prior to development. The work involves adaptation or development of equipment for operation in drill holes, and development of equipment to monitor the behaviour of mine openings. Techniques for numerical analysis are being developed.

24.4.17 The Division is co-operating with ACIRL in studying alternative mining methods not commonly in use in Australia, the aim being to improve overall recovery of coal from Australian resources in areas where underground coal mining is practised.

24.4.18 Computer simulation of stoping systems is being carried out at the University of Queensland with financial support from MIM Holdings Ltd and AMIRA. To date, work on sub level caving and open stoping has been done with a view to maximising metal recovery and minimising dilution.

24.4.19 At the University of Melbourne, two research students are involved in computer simulation of mining activity in various regions of an underground mine. Zinc Corporation Ltd is sponsoring the work.

24.4.20 At the School of Mining, University of NSW, one full-time research student, with some assistance, is using a Laplace analog computer

(one of only three in the world) to determine the effect of working methods and sequence of extraction of a coal seam on the strata pressures and the long term stability of the workings. The project is funded by a grant from the National Coal Research Advisory Committee (NCRAC).

24.4.21 At its Central Research Laboratories, BHP has a staff of five professional workers engaged in assessing alternative schemes for the transportation and beneficiation of coal. Major emphasis is on the simultaneous transportation and beneficiation in a pipeline.

ROCK BREAKAGE

24.4.22 ICI Australia Ltd employ 25 professionally qualified personnel on product development related to the manufacture of explosives. The mining industry is a major user of explosives. Two professionals with ICI are engaged on the study of blasting physics and rock dynamics. The theory of rock fragmentation caused by controlled blasting has been developed by means of a mathematical model. The model is now being used to predict crack patterns and fragmentation in practical mining situations at Mt Isa, Mt Newman, Hamersley and other mines.

24.4.23 MIM Holdings Ltd and the Mt Newman Mining Company funded a feasibility study at the Julius Kruttschnitt Mineral Research Centre, University of Queensland, for a research project into rock breakage and fragmentation by explosives. The results of the study were presented to AMIRA members and other interested parties. A proposal for a major project is being circulated among potential sponsors.

24.4.24 Two research students and a professional officer at the School of Mining, University of NSW, are studying the application of free-rolling cutters to the mechanised excavation of rock. The aim is to establish criteria basic to the design of efficient, rock-excavating machines and for improving the performance and range of application of mechanised mining systems.

24.4.25 The Queensland Department of Mines supports a project at the University of Queensland for the study of rock fracture associated with rock-cutting machines.

HAZARD DETECTION

24.4.26 The CSIRO Division of Applied Geomechanics has one professional looking specifically at hazard detection and avoidance in coal mines. The aim is to determine the mechanisms causing specific mining hazards such as outburst or roof fall, in various mining environments so that either hazard-prone areas can be identified, or methods to reduce the risk can be introduced.

24.4.27 The NSW Department of Mines has three professional officers working on various aspects of safety in coal mines. With assistance from

the AAEC, the Mines Department's Chemical Laboratory and Coalfields Branch have developed a gamma-ray back-scatter instrument for estimating the volatile content of coal-mine roadway dusts. Work continues on the evaluation of the explosion characteristics of New South Wales coal. A mobile, gas laboratory is used for research and for monitoring the atmosphere in mines.

24.4.28 The Queensland Mines Department sponsors research at ACIRL into effective systems of ventilation for use during the extraction of pillars in seams that are liable to spontaneous combustion. One professional is involved.

24.4.29 The Queensland Mines Department also sponsors two projects at the University of Queensland, one being a study of the susceptibility of various coals to spontaneous combustion, and the other of methane drainage from coal seams. Thiess-Dampier-Mitsui also supports the research on spontaneous combustion.

24.4.30 Many of the projects carried out at ACIRL are done with the aim of improving both the safety and productivity of mines. Aspects of mine safety being looked at include the prevention and control of spontaneous combustion, the prediction and prevention or control of outbursts and the pre-mining degasification of coal and gas-bearing strata.

OIL AND NATURAL GAS

24.4.31 Little research in this area is carried out in Australia. Esso Exploration and Production, Australia Inc. has a research agreement with Exxon Production Research Company, USA; of about \$1million which is spent annually with Exxon, half goes to research on mining and the remainder to oil processing R&D. Selected results are made available to Esso's partners in Australia.

24.4.32 BMR has two small projects, one being a study of enhanced oil recovery techniques for the Moonie Reservoir in Queensland and the other, a study of the behaviour of gas fields, uses a computer-based system.

GENERAL TECHNIQUES

24.4.33 The AAEC is developing techniques of nuclear analysis which could lead to better grade control in mines. At Mt Isa, one application is already being used by MIM Holdings Ltd to determine the copper content of drill cores and chippings.

EXPENDITURE

24.4.34 The following figures for approximate, present, annual expenditure on R&D in mining engineering were derived from information

supplied by organisations approached in the preparation of this chapter. When only a figure for personnel was supplied, an estimate was made, using a figure of \$40,000 for the annual expenditure associated with each professional worker. Although the Table gives approximate figures only, it does give a useful indication of the proportions spent on R&D.

TABLE 24.1
APPROXIMATE PRESENT ANNUAL R&D EXPENDITURE
ON MINING ENGINEERING

<u>(\$million)</u>					
<u>Commonwealth</u> <u>Government</u>		<u>State</u> <u>Government</u>	<u>Industry</u>	<u>Universities</u>	<u>Total</u>
<u>CSIRO</u>	<u>Others</u>				
1.1	0.8	0.3	3.2	0.3	5.7

24.5 DESCRIPTION OF MAJOR R&D PROGRAMS (MINERAL PROCESSING)

FERROUS METALS

Mineral beneficiation

24.5.1 There are two main centres of research - the Julius Kruttschnitt Mineral Research Centre working in conjunction with the Mt Newman Mining Co, and the CSIRO Division of Chemical Engineering working with Hamersley Iron Pty Ltd. The former group (two professionals plus support) is modelling iron ore crushing and screening plants; the work forms part of a joint project on simulation and control which commenced in 1968. The latter group (three professionals plus support) is currently studying the production of optimum-sized pellet feed for the next stage of processing; the project has been under way for three years. There are smaller groups, typified by the Western Australian Government Chemical Laboratories (one professional plus support) which is looking at the long term potential for beneficiation of the primary, banded iron-stone deposits of the Hamersley Basin.

Pyrometallurgy

24.5.2 In the area of iron and steel making the Broken Hill Proprietary Company Limited (BHP) maintains research centres at Newcastle, Port Kembla and Whyalla. This company's closely co-ordinated programs include blast furnace studies related to input materials, aerodynamics, thermodynamics and the evaluation of stove performance, while in the area

of steel making the current emphasis is on the improvement of yield and quality through de-oxidation, casting research, and the extension of the life of refractory linings for furnaces. The BHP work force in this area of 27 professionals plus support probably represents the largest single concentration of industrial, research manpower in science and technology in the country.

24.5.3 BHP has a major program on sintering of iron ores; this involves the Central Research Laboratories and the Works Research Laboratories at Newcastle and Port Kembla. A total of nine professional research workers (and support staff) are involved in these studies, which are aimed at improvements in the efficiency of blast furnace operations.

24.5.4 The CSIRO Divisions of Chemical Engineering and Process Technology are carrying out extensive studies on the direct reduction of iron ore and on the optimisation of parameters in the production of pellets of iron ore. The CSIRO team of 13 professional research workers (and support staff) works closely with Hamersley Iron Pty Ltd, which has 5 professional staff involved in iron ore pelletising studies. CSR Ltd is also involved in these areas of work with three professionals, plus support staff, at the Roseville (NSW) Research Laboratories.

24.5.5 A major effort on the direct reduction of iron ore has been mounted by Associated Minerals Consolidated Ltd in collaboration with the Azcon Corporation; the work has reached the stage where a demonstration plant with a sponge-iron capacity of 100,000 tonnes per annum has recently been commissioned.

24.5.6 The BHP Melbourne Research Laboratories are studying the production of heavy media ferrosilicon for mineral beneficiation. Molten ferrosilicon is atomised by high pressure water to produce a fine powder. Three professional workers, plus support staff, are involved.

General techniques

24.5.7 BHP is conducting an evaluation of ferrous burden and borehole cores from deposits being mined at present, and Hamersley Iron has committed a team of six professionals plus support to a long term study of the metallurgical characteristics of iron ore samples from its mines. On-stream analysis is a continuing subject for investigation by a joint Hamersley Iron Pty Ltd and CSIRO Mineral Physics team which is approaching the end of a five year study of the application of neutron activation analysis.

NON-FERROUS METALS

Mineral beneficiation

24.5.8 This is by far the most heavily supported area of research in mineral processing. The major national effort includes 19 professionals in the CSIRO Divisions of Chemical Engineering and Mineral Chemistry; 10 professionals at the Julius Kruttschnitt Mineral Research Centre; a group

of 9 professionals specialising in gravity concentration in the Launceston Metallurgical Laboratories of the Tasmanian Department of Mines; a similar number available for the internationally recognised, pilot plant operations of Amdel; a highly versatile, and efficient, pilot plant unit at Mt Isa; extensive facilities for the study of autogenous grinding, selective flotation and bulk flotation at Cobar; a comprehensive R&D centre at Warman International Ltd; specialist facilities at Mineral Deposits Ltd, Southport, and at Readings of Lismore; a continuing study of flotation at the University of Melbourne; and the various plant studies related to flotation, on-stream analysis, computer control and other aspects of mineral beneficiation which can be traced back through activities of the Broken Hill companies for 70 years.

24.5.9 These extensive research facilities reflect the fact that multi-million dollar, pilot plant investigations must often precede the development of a new mineral deposit. For example, Mimets Pty Ltd have for 20 years sought the metallurgical technology which would permit the economic development of the huge, fine-grained, lead zinc mineralisation in the HYC ore deposit at McArthur River. These studies have recently culminated in the setting up of a two tonne per hour, pilot plant, at what will be the future mine site, should the program of studies prove economically and technically successful. Another complex problem is presented by the Western Mining Corporation Ltd mineralisation at Yeelirrie. Five years of laboratory work has identified problems and possible solutions connected with the mining and treatment of the carnotite ore, but it will be necessary to set up a one tonne per hour, metallurgical research plant at Kalgoorlie for the next stage of the investigation. An 18-month study, which will involve 30 professionals plus support, is estimated to cost \$13million.

24.5.10 A unique feature of the research activities that are associated with mineral beneficiation has been the way in which two companies have forced their way to the forefront of equipment design and manufacture. Readings of Lismore Pty Ltd have specialised in the production of high-intensity, magnetic separators and their model RW775, Wet Separator now challenges the best that is offering on the world market. Mineral Deposits Ltd has become the major contributor to the development of new specific gravity separators for the world mineral industry. Both companies are also highly competent in the fields of electrostatic separation and general plant design; their current research programs are taking them into diverse areas of ferrous, non-ferrous and non-metallic mineral beneficiation.

24.5.11 Many mining companies, in addition to conducting their own research, make substantial contributions to the work of Amdel, of the universities and of CSIRO; this is done either directly or through the Australian Mineral Industries Research Association Limited (AMIRA). Company names which appear regularly in the lists of AMIRA sponsors include Australian Mining and Smelting Ltd, BH South Ltd, Electrolytic Zinc Company of Australasia Ltd and MIM Holdings Ltd. However, it is noted that the level of support for work on mineral beneficiation is tending to decline.

Pyrometallurgy

24.5.12 There is scattered research activity in many of the smelting centres. One of the largest efforts is mounted by the Broken Hill Associated Smelters Pty Ltd at Port Pirie (18 professionals plus support). At present, this Company's major emphasis is on projects concerned with the smelting and refining of lead and its by-products; for example, reflux refining of lead, production of saleable arsenical by-products, and the treatment of copper matte to recover copper and other metal values. CRA research teams, located at Sulphide Corporation Pty Ltd at Cockle Creek (Newcastle), are concerned with freeze-refining as a basis for continuously reducing the lead content of zinc, produced from a blast furnace to levels (1.4% lead) substantially below that of GOB grade ('Good Ordinary Brand' - metal accepted on London Metal Exchange). They are also studying briquetting as a means of improving treatment and utilisation of fines, such as smelter residues, which are associated with mineral processing. Sulphide Corporation Pty Ltd is also investigating techniques for the recovery of selenium (one professional plus support) and is undertaking studies of the design of tuyeres for blast furnaces. In addition, the various members of the CRA Group conduct collaborative work with organisations such as Amdel, the BHP Research Laboratories, CSIRO and the University of Newcastle.

24.5.13 MIM Holdings Ltd, in addition to a detailed investigation of the vacuum evaporation of copper matte and the reduction of converter slab by submerged combustion, is devoting considerable resources to improving the control of the existing reverberatory furnace and converter operation.

24.5.14 The total national effort depends to some extent on the 'old boy network' for rather loose, but effective, co-ordination. It frequently involves the banding together of groups who share an interest in the solution of a common problem. The CSIRO Divisions of Chemical Engineering and Mineral Chemistry have 21 professionals working on various projects in collaboration with many companies. Two such joint projects are the reflux refining of lead (with Broken Hill Associated Smelters Pty Ltd committing four professionals), and the fuming of tin from complex ores (with Abminco committing one professional).

25.5.15 The Western Australian Government Chemical Laboratories maintain a continuing effort on subjects of interests to the State and at present have 10 staff involved in pilot plant trials of a process for extracting vanadium from titaniferous magnetite. The high level of bismuth in Tennant Creek copper ore is unique and has provided problems with the concentrates. Peko Wallsend Ltd has just completed a study by five professional officers aimed at solving the problem and at the same time producing bismuth bullion of high purity.

Hydrometallurgy

24.5.16 The strong Australian emphasis of a few years ago is beginning to fade, but an imaginative group (four professionals plus support) flourishes in the Murdoch University, Mineral Chemistry Research Unit. Its main projects are concerned with solvent extraction in general and the hydrometallurgy of copper in particular; the work has been reflected,

since 1974, in a complementary effort by the Western Australian Government Chemical Laboratories (one professional). Monash University is studying the kinetics and mechanism of leaching and of cementation and the University of Sydney has a project on the extraction of nickel from laterites.

24.5.17 A group of four to five professionals plus support is working on the development of a process for leaching the flotation tailings obtained from the Andamooka copper-uranium ore body of Western Mining Corporation Ltd. This project will involve solvent extraction techniques and the development of suitable analytical methods for process control.

24.5.18 A research team (at present 2 professionals plus support) has for the past 10 years maintained a continuing investigation of aspects of leaching, ion exchange, solvent extraction and reactor design of potential relevance to the operations of the CRA Group. The large hydrometallurgy program of the CSIRO Division of Mineral Chemistry, which has been in existence for seven years, has recently been sharply curtailed and the nine professionals employed in 1976-77 have been reduced to four.

24.5.19 The Australian Atomic Energy Commission (AAEC) maintains a continuous effort which is currently four professionals, plus technical support, on aspects of uranium processing including new leaching techniques, solvent extraction and waste treatment.

Electrometallurgy

24.5.20 This subject overlaps the hydrometallurgy program. Key laboratories are those of Electrolytic Zinc, Comalco, and BHP, the latter concentrating particularly on the production of electrolytic manganese dioxide. At Townsville, Copper Refineries Pty Ltd has developed new tank-house technology and a team of 12 professionals is engaged in the commercial scale implementation of this work. There has been extensive collaboration with Mitsui, while MIM Holdings Ltd has co-operated in the process control studies. The CSIRO Division of Mineral Chemistry (three professionals plus support), the Murdoch University Unit, and the Universities of NSW, Newcastle, and Queensland are also working in this area.

General techniques

24.5.21 On stream, and static, bulk analysis, ore sorting, and process control are receiving considerable attention. The radio-isotope on-stream analysis system now widely used throughout Australia to analyse mineral slurries resulted from R&D by the AAEC, followed by plant testing by the AAEC, Amdel and The Zinc Corporation. This system is being exploited commercially by Amdel, under license to the AAEC, for the world market. The AAEC is also undertaking R&D into nuclear techniques for the on-line determination of energy, ash and moisture content of coal; this is described in chapter 18 ('Energy'). Amdel and Cobar Mines Pty Ltd have developed new analytical instruments with both projects extending over 10 years; 2 professionals have been involved with this work at Amdel. Close attention to the development of atomic absorption and x-ray Fluorescence analysis by Mt Isa Mines Ltd has led to the introduction of instrumental

methods which provide analyses at a lower cost per assay than that incurred in 1968. A four year program of research on ore sorting conducted by CSR Limited (six professionals) has lead to the production of a computer-monitored prototype which separates minerals on the basis of their chemical composition. CSIRO Division of Mineral Physics and Western Mining Corporation Ltd have combined their research efforts in order to develop, design, build and test a radiometric, ore-sorting machine. Process control studies are supported by the CSIRO Division of Chemical Engineering (four professionals) and Cobar Mines Pty Ltd.

NON-METALLIC MINERAL PRODUCTS

24.5.22 The two main service groups are located at Amdel and in the ACI Technical Centre. There is also a large number of small groups scattered throughout various CSIRO Divisions (Mineralogy, Mineral Chemistry, Building Research, Materials Science), industrial laboratories and State Geological Surveys and Mines Departments.

24.5.23 Australian Consolidated Industries Limited (ACI) specialise in research on raw materials used for glass making. Current projects include a search for means of economically removing undesirable impurities, such as iron and chromium, from low grade sands. Some of this research is conducted in collaboration with the CSIRO Division of Mineral Chemistry. The CSIRO and Amdel programs include a significant effort on wastes. Monash University has built up a specialist team to study the pumping and settling of slurries of waste 'red mud' from the Bayer Process for purifying the bauxite used in aluminium production.

PROFESSIONAL MANPOWER

24.5.24 The following Table is reasonably comprehensive. The number of professional staff could be increased by at least 10% in any given year as a result of intensive, pilot plant studies.

TABLE 24.2

PROFESSIONAL RESEARCH WORKERS IN MINERAL PROCESSING

Abminco N.L.	7
Australian Atomic Energy Commission	8
Australian Consolidated Industries Ltd	16
Amdel	22
The Broken Hill Proprietary Company Limited	50
Comalco Limited	10
Conzinc Riotinto of Australia Limited	41
CSR Ltd	19
Electrolytic Zinc Company of Australasia Ltd	15
ICI Australia Limited	6
MIM Holdings Ltd	13
Mineral Deposits Ltd	10
Readings of Lismore Pty Ltd	10
CSIRO	83
Department of Mines, Tasmania	9
WA Government Chemical Laboratories (WA Department of Mines)	12
Murdoch University	9
Julius Kruttschnitt Minerals Research Centre (University of Queensland)	16
TOTAL	<u>356</u>

**CAUTION
AEROSPACE**

Photograph: Transonic wind tunnel testing at the Aeronautical Research Laboratories of an advanced technology (supercritical) aerofoil.
(Photograph courtesy Aeronautical Research Laboratories).

CHAPTER 25

AERONAUTICS AND AEROSPACE

25.1 INTRODUCTION

DESCRIPTION OF AREA COVERED

25.1.1 The term 'aeronautics and aerospace' covers the science and technology of flying through the atmosphere and through space. At one time, it seemed that Australia might be involved with the development and operation of space vehicles; that interest has now lapsed although there is active concern with the payloads of such vehicles, especially for communications, weather forecasting and resource monitoring. For this reason, aeronautical technology is much more important to Australia than aerospace technology, and in what follows, the latter will seldom be mentioned.

25.1.2 It is worth stressing that aeronautics is a high technology area with severe operational penalties for excessive structural weight and lack of aerodynamic and propulsive efficiency. Unlike other forms of transport, engine or structural failure is at least hazardous. The environment can be hostile, with poor visibility, wet runways, wind shear, hail and extremes of temperature and pressure. Civil and military operations both lead to the need for complex sensors to be carried, and for light and reliable data handling and data presentation systems.

25.1.3 Historically, the Commonwealth Government took a major step in 1937 by inviting H.E. Wimperis, of the United Kingdom, to recommend what should be done to develop the local aeronautical industry. His report largely followed local recommendations and led to the establishment of a Chair of Aeronautics at the University of Sydney, and the Division of Aeronautics which was originally in CSIR but is now separated as the Aeronautical Research Laboratories (ARL). These were to support the factories, the Commonwealth Aircraft Corporation (CAC), Government Aircraft Factories (GAF) at Fishermen's Bend and de Havilland in Sydney. These factories produced large numbers of military aircraft during World War II, especially during the later part. At the peak of production, some 44,000 people were employed in aircraft manufacture.

25.1.4 At the end of World War II, the Australian industry was manufacturing front-line aircraft, mainly of overseas design, for the RAAF and maintaining a wide variety of aircraft for the Allies. In general, the industry had the necessary industrial technologies to manufacture complete aircraft including airframes, piston engines, equipment and instruments. The industry also had a high level of design and development competence as exemplified by the prototype CA15 fighter which was equal to any other

piston engine fighter at the time but was not put into production because, by then, the war had finished.

25.1.5 Since the war, technology development has been sustained through a number of licence manufacturing programs, indigenous Australian product programs and, lately, offset programs, but not at the rate of technology development overseas. The result is that, while Australia is ideally suited to air transport and military aviation (benign climate, flat terrain, relatively long distances between centres of population and a lack of adequate road or rail systems in many areas) the capability for design and production of indigenous aircraft has not kept pace with overseas technological development [1]. At present, some 5,500 people are employed in aircraft manufacture.

25.1.6 The reason for this slippage is basically a matter of economics. Australia does not have the military or civil market to justify the expenditure of large amounts of money on research, development and tooling cost associated with full production of advanced aircraft. Major military or civil needs have been met by overseas purchase or manufacture locally under licence of overseas designs.

25.1.7. Nevertheless, Australian industry today does have the design, development, manufacturing and management expertise required for the local manufacture of aircraft in the category of jet trainers, light transports, such as the Nomad produced by GAF, and some missiles. However, even with these aircraft, economic considerations would dictate that most of the basic material and components would be procured from overseas.

25.1.8 Examples of the advances made in design, development and manufacturing technologies in Australia are:

- GAF has a world-class facility in bonding technology. This is a technique for joining metal to metal which is now fairly common in modern aircraft manufacture.

- GAF has a design team whose general capability is exemplified by the Nomad aircraft and Ikara missile. The team includes skills in aerodynamics, structural analysis, systems integration, etc. CAC has developed particular expertise in fatigue analysis which is used by the RAAF.

- GAF has a high class facility skilled in the manufacture of reinforced plastics. All production work so far has been with glass reinforced plastics, but experimental work is now going on with carbon and boron reinforced plastics.

25.1.9 Like aircraft, target drones and missiles are generally purchased overseas, although there are three notable exceptions: the Ikara anti-submarine weapon system, and the Jindivik and Turana target drones all of which are currently in production.

25.1.10 To complete the scene, there is a light aircraft industry, including agricultural and ultra light aircraft, and gliders. However, the demands for R&D in these areas are not great; this is easily understood for the latter two are recreational rather than commercial ventures. In the agricultural area, Transavia has developed a market for their Airtruck. It is understood that the company would like to be able to do more development work, but realises that it would be difficult to maintain a competitive price for the product.

25.1.11 In general, with the change of emphasis from local manufacture to overseas purchase, R&D effort has been mainly directed towards operator problems, although effort is still needed to support the limited local developments. There is an increasing awareness internationally of the very real gains to be made from close examination of operational problems. An often-quoted figure for the cost of ownership of a military aircraft is 30% for initial purchase and 70% for support during its operational life. A much greater potential for savings obviously lies with the latter figure. Similar figures would be expected for civil aircraft. Savings in cost during operations should come both from a feed-back of operational information to the design of new aircraft, and from a better understanding of the factors leading to component deterioration and how such deterioration can be detected and appropriate action taken.

25.2 ORGANISATION, POLICIES AND FUNDING

POLICIES AND AGREEMENTS

25.2.1 Although the manufacturing industry has not developed as initially expected, the operating industry, especially in the civil area, has flourished and has established an enviable record for safety and efficiency. Major operators are, of course, QANTAS Airways Ltd on international routes, and TAA and Ansett Transport Industries (Airlines) within Australia. The latter two cater for well over 90% of internal airline business.

25.2.2 The Air Transport Group of the Department of Transport is responsible for flying safety and operational support needs, mainly aerodromes and navigation aids. In this Chapter R&D associated with ground-support systems such as navigation aids and aerodromes for civil operations is not included (see Chapter 35, Transport, for information on these areas). Again, each Service (RAAF, RAN, Army) is responsible for the operation of its own aircraft, although the RAAF, by agreement, exercises some technical responsibility for Army aircraft.

25.2.3 R&D support for the factories, the operators and the airworthiness authorities is available from:

- . engineering elements within their own organisations, or associated organisations.
- . government laboratories, particularly the Aeronautical Research Laboratories, and the Defence Research Centre Salisbury (DRCS), formerly the Weapons Research Establishment.
- . universities, particularly those departments with an aeronautical interest.
- . overseas R&D resources.

25.2.4 As will be seen later, the major contributors to R&D are the Aeronautical Research Laboratories and the Defence Research Centre, Salisbury. These organisations are in the Department of Defence, and primarily support military aviation, although civil work is undertaken, the cost being usually recovered.

25.2.5 Australia is associated with a number of international agreements which have an influence on local R&D. The major ones are:

- . The Technical Co-operation Program (TTCP) which is concerned with identifying important gaps in the military technology base and developing joint or complementary R&D programs to remedy the situation. The United States of America, Australia, Canada, New Zealand and the United Kingdom are members;
- . the Air Standardisation Co-ordinating Committee (ASCC) which fosters standardisation of air material between member countries, and thus stimulates R&D in determining such standards. Member countries are the same as in TTCP;
- . the Mutual Weapon Development Data Exchange Agreement (MWDDEA) between the United States and Australia which enables information to be exchanged between nominated project officers in selected areas of mutual interest;
- . the Commonwealth Advisory Aeronautical Research Council (CAARC) which has co-ordinators in relevant fields in each country, and which is responsible for exchanging information on research programs and for developing joint or complementary programs where appropriate. Australia, Canada, India, New Zealand and the United Kingdom are members. Australia contributes an annual amount of \$5,000 to support the Central Secretariat in London;
- . the International Civil Aviation Organisation (ICAO) which recommends action to member countries on matters identified by its Council as being of importance. The matters are usually considered by specialist panels in many of which Australia has made substantial contributions. The Australian subvention was \$263,000 in 1977-78.

25.2.6 Within Australia, the Australian Division of the Royal Aeronautical Society is active, with branches in Adelaide, Canberra, Melbourne and Sydney. In addition, the Institution of Engineers Australia caters for all the engineering disciplines; it has an Aeronautical Branch in the Victoria Division, while in other Divisions, aeronautical interests are covered under headings such as Mechanical Engineering. Other more specialised research interests are helped by relevant learned societies such as the Australian Institute of Physics, the Institute of Metals, and the American Society of Mechanical Engineers.

ORGANISATION

25.2.7 The main laboratories (ARL, DRCS, and the Materials Research Laboratories (MRL)) are part of the Defence Science and Technology Organisation in the Department of Defence, and each reports to the Deputy Chief Defence Scientist. These laboratories are totally funded from the Defence vote, and the costs recovered for any work performed outside defence interests are returned to revenue and credited to the department.

25.2.8 The Government Aircraft Factory (GAF) finances its operations from a trust fund and income from work undertaken. It receives a contribution from the Government for the maintenance of reserve capacity; this reflects the Government's wish to maintain a certain minimum capacity at GAF to meet any emergent threat, and recognises that the current workload is not adequate for that purpose.

25.2.9 The Commonwealth Aircraft Corporation (CAC) and Hawker de Havilland (HDH), like GAF, also receive a government contribution for the maintenance of reserve capacity. These government contributions are not subsidies but are reimbursements to the companies of expenses incurred in maintaining, to standards set by Government, certain overhead resources necessary for Defence manufacturing and technical support activities.

25.2.10 The RAAF operates an Aircraft Research and Development Unit (ARDU) at Edinburgh, South Australia. It has on strength nine civilian scientists seconded from the Defence Research Centre, Salisbury to assist in flight trials work.

25.2.11 The Air Transport Group of the Department of Transport does some 'in-house' R&D, but also seeks fairly extensive assistance from outside. It funds work in CSIRO and at the Aeronautical Research Laboratories; it keeps in touch, particularly with ARL and MRL, on relevant aspects of military research; when desirable it contracts to industry, and it supports financially some university research on corrosion.

FUNDING

Industry expenditure

25.2.12 Military Operations: The annual cost of maintaining the RAAF, and the air elements of the RAN and Army would amount to about one-third of the total Defence vote, that is about \$700million and involving about 30,000 people. It should be noted that some of this expenditure is in support of civil operations.

25.2.13 Civil Operations: The annual costs of the civil fleet operators were around \$1,000million in 1974-75 [2]. Not all of these costs would be concerned with aeronautics. With some allowance for this and for inflation, the annual cost for aeronautical aspects is around \$700million and involving about 25,000 people.

25.2.14 Manufacturing Industry: The majority of aeronautical work carried out by CAC, GAF and HDH is for defence, and is covered above. Limited civil work in these factories, and in Transavia and other companies would be expected to cost around \$30million and involve the employment of some 2,000 people.

25.2.15 General Aviation: This covers areas such as private and business aircraft, flying training, charter, agricultural aviation and small commuter airlines. The annual expenditure and employment at present has been estimated [3] to be around \$130million and 4000 people, respectively. In summary, the industry spends around \$1500million per annum and employs about 61,000 people.

R&D expenditure

25.2.16 Estimates have been made of the cost of aeronautical R&D, are shown in Table 25.1.

25.2.17 The total cost for R&D support of the industry is \$19.7million, or 1.4% of the industry costs. Most of this expenditure relates to military aviation, undertaken by government laboratories.

25.2.18 It has been claimed that most aeronautical research is carried out in the Aeronautical Research Laboratories and the Defence Research Centre, Salisbury. On an expenditure basis, it could be argued that the RAAF's Aircraft Research and Development Unit, and the Government Aircraft Factories are equally important. It should be remembered however, that full-scale flight testing is costly to perform and ideally, is used to validate theoretical or laboratory experimental predictions. Similarly, exploratory, development-type work carried out by the Government Aircraft Factories is expensive in manpower and material; it is essential, however, if projects are to be satisfactorily planned and executed.

TABLE 25.1

ESTIMATED EXPENDITURE ON AERONAUTICAL R&D, 1977-78

Tertiary Education Institutions	\$ 0.5million
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Government Laboratories/Units

ARL	\$ 6.3million	
DRCS	\$ 3.5million	
ARDU	\$ 4.7million	
Other	\$ 0.4million	\$14.9million

Industry

GAF	\$ 3.5million	
CAC	\$ 0.2million	
HDH	\$ 0.4million	
Other	\$ 0.2million	\$ 4.3million

25.3 DESCRIPTION OF R&D ESTABLISHMENTS

25.3.1 The major establishments are the Aeronautical Research Laboratories and the Defence Research Centre, Salisbury with most experimental flying being carried out by the Aircraft Research and Development Unit at Edinburgh in South Australia. Within the Defence Research Centre, Salisbury, the Weapons Systems Research Laboratory is the major contributor in the field of aeronautics. Of the factories, the major contributor to R&D is the Government Aircraft Factories.

25.3.2 The Aeronautical Research Laboratories is part of the Defence Science and Technology Organisation in the Department of Defence. The Chief Superintendent reports to the Deputy Chief Defence Scientist. Its annual budget is about \$8.4 million, about \$6.3million of which is on aeronautical R&D. There are about 170 professional staff engaged on this work. It is particularly concerned with all problems related to the operation of military aircraft. Its fields of expertise include structures, aerodynamics, propulsion with air-breathing engines, aircraft materials and systems especially those with a man in a control loop.

25.3.3 The Defence Research Centre, Salisbury (DRCS) is formed of four separate laboratories, three of them headed by a Chief Superintendent reporting to the Executive Controller, Australian Defence Scientific Services. Almost all of the aeronautical R&D is carried out in the Weapons Systems Research Laboratory. The annual budget of DRCS is about

\$64.7million and about \$3.5million of this is expended on aeronautical R&D. There are 75 professional staff engaged on work in this area. In the field of weaponry their main contributions are to aerodynamics, rocket propulsion, control and guidance systems, and to systems analysis.

25.3.4 The Aircraft Research and Development Unit is an operational unit of the RAAF specifically charged with the responsibility for flight testing, or for flying in support of R&D work, both military and civil. Its annual budget is about \$4.7million and this is all expended on aeronautical R&D. There are 12 test pilots and 14 engineers in uniform and 9 civilian professional staff are seconded from DRCS. Its areas of interest are aircraft flight testing to provide information on performance and handling, and for flight clearance. Flight instrumentation and data analysis are important elements in the work.

25.3.5 The Government Aircraft Factories is part of the Department of Productivity, but most of the work is for defence purposes. Its annual budget is about \$35.5million, of which about \$3.5million is expended on aeronautical R&D. There are 43 professional staff and the main field of interest is R&D in support of aircraft, drone and weapon projects.

25.4 DESCRIPTION OF MAJOR R&D PROGRAMS

AERODYNAMICS

25.4.1 The Aeronautical Research Laboratories and the Defence Research Centre, Salisbury are the main contributors to aerodynamic research in Australia. By agreement, the work at ARL mainly deals with aircraft, while that at DRCS is mainly concerned with weapons. Some research is also conducted in tertiary institutions but this work is usually associated with undergraduate or postgraduate study rather than as a contribution to Australia's specific R&D needs.

25.4.2 Most R&D work requires facilities for flow visualisation or force measurement. Major wind tunnels in Australia are listed in Table 25.2.

25.4.3 A significant part of the work of ARL has been directed towards an understanding of the stability and control (behaviour) of aircraft configurations, both fixed and rotary wing, as influenced by the aerodynamics. Basically, this requires extensive aerodynamic data - measured by wind tunnel or flight, or estimated from generalised data - details of the control system, physical data on the aircraft and access to a computer to solve the equations of motion. If the study is being made of an existing aircraft, it is then wise to carry out sufficient flights tests to

validate the mathematical model. Such models can be used to predict aircraft behaviour in support of aircraft development, aircraft modifications and in exploring operational boundaries. Mathematical models of the behaviour of the Mirage and the Wessex helicopter have been developed, and those for the F111 and the Sea King are under development.

25.4.4 Wind tunnel measurements to support the mathematical modelling work are similar to those required in the design and development of aircraft. Although only limited development of indigenous aircraft is occurring, some effort is required for the testing of local designs, including developments of existing items such as Jindivik, Turana, Ikara and Nomad.

25.4.5 Another area of considerable importance is the determination of unsteady aerodynamic derivatives for the estimation of flutter boundaries. Under some circumstances, incipient vibration can interact with the aerodynamic forces occurring in flight and build up into large vibrations which render the aircraft uncontrollable. This phenomenon is known as flutter, and occurs at a critical value of the airspeed, which clearly should be well above the maximum speed permitted in operations. A theoretical approach backed by wind tunnel tests is being developed; such tests are essential at transonic speeds where theoretical results are likely to be in error due to shock wave-boundary layer interactions.

25.4.6 The areas listed in 25.4.5 are related to external flow. Internal flow in ducts, compressors, turbines and combustion chambers are important for modelling propulsion systems and for solving related operational problems. Again, engine intakes, especially at high speeds, with shock wave and boundary layer interactions, can be a serious source of problems; such intakes include an element of external flow as well as internal flow. Typical problems involve the determination of the effects of an asymmetric velocity distribution at compressor inlets on the stalling and surge behaviour of an engine and on the vibration and flutter characteristics of the compressor blades.

25.4.7 In carrying out work such as that described above, some attention must be paid to developing the facilities and techniques to tackle both the present day problems, and those of the future.

25.4.8 While the above areas absorb most of the available resources, the services of the laboratories are available to help with defence problems related to aerodynamics, and with civil problems where equipment or knowledge is not available elsewhere in Australia. A typical example of a service need has been the use of the wind tunnel to develop exhaust stacks for naval vessels to ensure that working areas on the ships are kept clear of exhaust fumes. In the civil field, the low speed tunnel has been used to develop vortex generators which will improve the flow into the propellers and over the rudders of merchant ships and so reduce vibration and improve manoeuvrability.

25.4.9 The Defence Research Centre, Salisbury (DRCS) is concerned with research and development in missile flight dynamics, aerodynamics (generally at high speed) and aero-ballistics. To support its R&D

programs, the DRCS has extensive laboratory, wind tunnel and workshop facilities. Flight trials requiring full-scale range facilities are carried out at the Woomera Range and the Army Proof and Experimental Range, Port Wakefield, SA. In addition, a versatile compressed-air gun and associated missile-borne instrumentation have been developed to perform tests on models in free flight at Salisbury. For many years the DRCS has worked closely with the UK and USA on research covering bomb ballistics, shell ballistics and free-flight rockets.

TABLE 25.2
MAIN WIND TUNNELS IN AUSTRALIA

<u>Tunnel Location</u>	<u>Test Section</u>	<u>Max.</u> <u>Speed</u>	<u>Max.</u> <u>Reynolds</u> <u>No.</u>	<u>Power</u>	<u>Running</u> <u>Time</u>
LOW SPEED					
ARL	2.74m x 2.13m	107 m/s	2.24×10^6	653 kW	continuous
Monash Uni.	2.00m x 2.00m	100 m/s	2.00×10^6	400 kW	continuous
Uni.of Sydney	2.10m x 1.50m	31 m/s	6.40×10^5	60 kW	continuous
Uni.of Sydney	1.20m x 0.90m	55 m/s	1.10×10^6	56 kW	continuous
TRANSONIC					
ARL	0.81m x 0.53m	M = 1.4	2.40×10^6	2050 kW	continuous
SUPERSONIC					
DRCS	0.38m x 0.38m	M = 2.8	2.50×10^6	3000 kW	continuous
DRCS	0.15m x 0.18m	M = 4.3	35.00×10^6	-	40 seconds
ARL	0.38m x 0.39m	M = 1.6	5.50×10^6	2840 kW	continuous
ARL	0.12m x 0.12m	M = 3.0	11.50×10^6	1500 kW	continuous
Uni.of Sydney	0.13m x 0.13m	M = 4.0	6.50×10^6	-	200 seconds
Uni.of Sydney	0.15m x 0.07m	M = 4.0	15.00×10^6	-	200 seconds
HYPERSONIC					
ARL	0.21m (dia.)	M = 6.0	2.30×10^6	-	70 seconds
		M = 7.5	-	-	
ANU	0.30m (dia.)	10 km/s			2 millisec.

25.4.10 A task now well advanced is concerned with the flight clearance of air weapons from Service aircraft. A novel technique of testing in a wind tunnel has been devised to simulate the motion of weapons while still

close to the aircraft. In this way the critical conditions affecting the safety of the aircraft and the accuracy in the delivery of the missile can be identified.

25.4.11 Effort is being directed toward the study of terminal correction techniques applied to conventional artillery shells and rockets. The concept of terminal guidance is seen to offer a new avenue for exploiting the most recent advances in rocket and gun technology and to provide a potential for significant improvements in the effectiveness of what were purely ballistic weapons.

25.4.12 Theoretical work of a fundamental nature is aimed at exploiting the capability of modern computers to carry out the very complex calculations needed to simulate aerodynamic flow fields. A finite element method is under development to estimate the flow field around missiles, particularly at subsonic and transonic speeds. Additional work on the dynamic behaviour of missiles in nonlinear flight involves the estimation of parameters by computer-based methods, and results in the extraction of aerodynamic data of high quality from test flights.

25.4.13 DRCS also performs feasibility and project studies on ballistic weapons in response to Service requests. Detailed studies of field artillery have been made to determine how the accuracy of fire might be improved. In the context of battle-field surveillance, technology associated with the design and operation of small, remotely piloted, aircraft is under examination to obtain data and experience relevant to current military interests.

25.4.14 Like ARL, DRCS is interested in developing facilities to meet present and future needs. In addition to the developments mentioned above, a short, enclosed range is being built to test the ballistics of low calibre ammunition (up to 30 mm).

25.4.15 Only two other (Government) agencies will be mentioned in relation to aerodynamic R&D; they are the CSIRO Division of Mechanical Engineering and the State Electricity Commission of Victoria. Although their work is directed to non-aeronautical application, some is relevant to aeronautics. The CSIRO Division of Mechanical Engineering is concerned with fans, ventilating and air conditioning systems, aerodynamic noise, flow through ducts and aerial delivery of sprays and fertilizers. For obvious reasons, the State Electricity Commission is concerned with flows in plumes and furnaces, and with atmospheric contamination.

25.4.16 The aerodynamic research carried out in tertiary institutions is very diverse; it is usually related more to fluid mechanics than to aeronautics. Subjects chosen for study are no doubt influenced by the interests of the staff and the test facilities available. At the Australian National University, a strong interest has developed in hypersonic (greater than Mach 5) rarified gas and reacting flows, and a unique shock tunnel has been developed for studying such flows. At Monash University the main interest is in flows associated with the earth's boundary layer. A significant program of work, concerned with flows around tall buildings and over built-up areas has been developed by use of a low-speed wind

tunnel. The University of Sydney has developed an interest in using a computer to simulate hypersonic rarified gas flows; this work has attracted considerable support from the United States. Other tertiary institutions involved with aerodynamic work are the University of Melbourne, the University of NSW, the University of Tasmania, the University of Queensland, the James Cook University, the University of Adelaide and the Royal Melbourne Institute of Technology.

STRUCTURES

25.4.17 There is only one laboratory significantly engaged in aircraft structural research in Australia, the Aeronautical Research Laboratories (ARL). However, structural design and development are important elements in factories concerned with the development of aeronautical products. While such factories will improvise special test rigs in many cases, some complex testing will be carried out on their behalf in special facilities such as those available at ARL. Again, some R&D is performed in tertiary institutions.

25.4.18 Structural problems associated with the operation of aircraft, both civil and military, generally dominate the R&D scene: aircraft fatigue and aeroelasticity are probably the most important. Other areas are vulnerability of military aircraft and crash-worthiness of civil aircraft.

25.4.19 Facilities for structural testing at ARL are quite extensive. They are generally divided into:

- . mechanical tests;
- . full-scale structural tests - static, dynamic and fatigue; and
- . component fatigue tests.

25.4.20 There are three main types of tasks carried out in the Mechanical Testing Laboratory, namely:

- . structural testing of components;
- . determination of mechanical properties of materials (standard tensile properties, fracture toughness etc.); and
- . experimental investigations for structural research projects.

The Mechanical Testing Laboratory is temperature-controlled and is registered by the National Association of Testing Authorities (NATA) in the field of mechanical testing. Among the test equipment are four universal testing machines which cover a range of load capacities up to 2.65 meganewton (MN). The 2.65 MN machine is physically very large being able to accommodate test articles up to 5 metres long. It is often used for testing large structural assemblies for civil engineering projects,

such as components of bridges, oil drilling rigs, and large cranes, as well as for testing aircraft components.

25.4.21 Facilities are also available for carrying out full-scale tests of aircraft structures. Such tests are conducted in a bay which has a reinforced floor of area 926 square metres. Movable portal frames are available which can be positioned to suit the type of structure to be tested and the floor has strong points to which the structure may be tied down. Hydraulic power is available throughout the area. Both static and fatigue tests of major aircraft assemblies, such as wings and fuselages, or even complete aircraft, can be carried out in this area; but the facilities are now mainly used for fatigue tests. Three fatigue test rigs can be run concurrently using remote computer control; data recording equipment is available with a capacity 250 channels.

25.4.22 The H.A. Wills Fatigue Laboratory contains a variety of bending, and axial load, fatigue test machines. These have load capacities ranging from 2.5 kilonewton to 1 MN, and several are electro-hydraulic, servo-controlled machines incorporating computer, and punched tape, control systems.

25.4.23 The main experimental tool for determining the internal load distribution in a structure is the electric resistance strain gauge. In the past, gauges were manufactured at ARL, but the practice now is to buy the gauges from overseas. Such gauges are also frequently used as sensing elements in control systems for structural testing, and a considerable effort was expended on their use during the development of the electro-hydraulic servo-controlled test rigs used in the full scale tests of aircraft structures referred to earlier. A key element in this system is a mini-computer which not only calls up the loads to be applied but also monitors a number of safety systems designed to prevent accidental overloads.

25.4.24 The development of methods of assessing the fatigue life of an aircraft has been continued at ARL for many years. Such assessments are of importance in the overseas procurement of aircraft, in the operation of aircraft to meet Australian requirements under Australian conditions, and in developing local aircraft designs; they are particularly important in examining possible extensions to the life-of-type of operational aircraft. Usually, an assessment requires support from full-scale fatigue tests to provide a satisfactory answer. Research on fatigue has included the development of statistical methods for life estimation based on reliability theory, investigations of the nature of fatigue damage in materials, studies of environmental and load history effects, and the accumulation of generalised fatigue data.

25.4.25 In assessing fatigue life, the following data are required, and work is conducted on all of them at ARL:

- the loading history - aircraft mission, atmospheric turbulence, landing, taxi and take-off loads are relevant;

identification of the critical areas where fatigue failure might occur;

fatigue characteristics of the materials and structural elements making up the structure, and any environmental effects on those characteristics;

if possible, experimental data on similar structures to give an indication of the variability in the likely fatigue behaviour of nominally identical structures.

25.4.26 Loads on RAAF operational aircraft are measured using airborne recorders; they are influenced by mission and atmospheric effects. Special flights are conducted to measure turbulence, while tower mounted and ground-based instruments are being used in Queensland to study the turbulence associated with tropical thunderstorms. This work is part of an endeavour to generate load spectra appropriate to Australian operations.

25.4.27 Among other things, the effects of contaminants in bolt holes on the fatigue characteristic of joints in D6ac high strength steel are being examined. These results are of relevance to the life of the F111 aircraft.

25.4.28 In questions of both the static and the fatigue strength of a structure, there is a need to know the internal stress distribution. Current areas of interest include the finite element method of stress analysis, fracture mechanics and composite materials.

25.2.29 A small, general purpose, finite element program has been devised and is running on the ARL computer, but preliminary consideration is now being given to obtaining a substantially more extensive program. One of the most comprehensive is NASTRAN which was developed in the United States by NASA; access to this is available in Melbourne through a commercial computing centre, but it is expensive to use.

25.4.30 Fracture mechanics is an important theoretical tool for assessing the 'damage tolerance' characteristics of an aircraft structure; i.e. the behaviour of the structure when it is weakened by the presence of cracks. One important application of fracture mechanics was in the recovery program of the F111 aircraft. Here ARL was called on to give advice to the RAAF over an extended period prior to the aircraft's acceptance by Australia. Current research work in fracture mechanics is directed towards the development of numerical methods for determining the stress intensity factor which is the key parameter in the present theory.

25.4.31 Composite materials, such as plastics reinforced with carbon fibres are finding ever-increasing applications in aircraft structures and it is likely that the next generation of high-performance RAAF aircraft will contain significant amounts of these materials in their airframes. Some experience is being gained in structural applications of fibre reinforced plastics.

25.4.32 A knowledge of the vibration characteristics of an aircraft structure is required for flutter analysis. One factor which can markedly affect the critical flutter speed is the presence of external stores hung on the aircraft. Whilst the manufacturer of an aircraft will nowadays normally establish the flutter clearance of the basic aircraft, an Australian operator (e.g. the RAAF) may have an individual requirement for external stores which necessitates a separate flutter clearance.

25.4.33 A substantial facility has been developed for vibration testing and analysis. Vibration exciters covering force levels from 4 to 2500 newton are available and with them it is possible to excite both small and large structures, ranging from turbine blades to complete aircraft (and also other large structures such as ships or bridges). In recent years several series of vibration tests have been carried out on various versions of the Nomad aircraft.

25.4.34 In addition to the development of improved methods of flutter analysis, research activities in this general area include the development of improved theoretical methods for determining the dynamic response of an aircraft to atmospheric turbulence or to control movements, the investigation of more rapid and more accurate methods for the experimental determination of an aircraft's vibration characteristics, and studies of the vibrations of helicopter blades.

25.4.35 The above work is generally directed towards aeronautical problems; much of the experience gained is also applicable in other areas. For example, several problems of ship vibration have been successfully solved.

25.4.36 An important feature of any military aircraft is its vulnerability to attack; associated with this is the question of the lethality of anti-aircraft weapons. Experience has been built up in this area, initially by assessing damage sustained by a large number of target aircraft in trials at the Woomera range. Effort is also devoted to questions associated with the safety of occupants of an aircraft during a crash. For example, a fairly extensive study has been made of the performance of aircraft seat-belts. Finally an Accident Investigation Service is maintained to provide assistance, on request, both to the Services and to the Civil Airworthiness Authorities. A limited amount of research has also been carried out in this area; in particular, on how the disposition of wreckage on the ground can be used in deducing the sequence of events that occurred in the break-up of an aircraft in flight.

MATERIALS

25.4.37 Advances in aeronautical technology are intimately connected with advances in materials. It is easy to trace the evolution of the structures of aircraft with increasing speed - wood with fabric covering, aluminium alloy, titanium and high strength steels and fibre-reinforced composites.

Again, developments in propulsion technology have been dependent on the availability of high temperature materials such as the nickel-chromium alloys and, more recently, on the emergence of ceramic materials.

25.4.38 In turn, the use of those materials has made it necessary for the materials scientist to characterise the various alloys, to establish their performance for design purposes; to understand their behaviour, particularly in the working environment; to evolve protective systems when the effects of that environment are unacceptable; and to develop inspection techniques or monitoring systems to ensure the satisfactory operation of the product. There is little work in Australia on producing alloys for the aircraft industry; most aircraft materials of high quality are purchased from overseas as the limited production for any local requirements would prove unattractive to industry and would certainly be more expensive than direct overseas purchase.

25.4.39 ARL is the main contributor to the above field. An area of concern is the processes by which materials degrade in a service environment, and ways in which such degradation may be ameliorated, predicted and monitored. Typical degradation processes are:

- . crack initiation and propagation under various loading sequences, particularly in relation to the microstructure of the materials;
- . mechanisms by which the environment can alter crack initiation and propagation.

This work is directly related to the lives of aircraft structures and engine components. At least, it should be able to help in predicting the susceptibility of materials to fatigue, and in tracing the fatigue process to final failure. It may also lead to ways of retarding or inhibiting undesirable environmental effects; some environments may improve the performance of materials.

25.4.40 Leading on from the above work is the development of repair schemes for cracked metal components using boron-fibre composite 'patches'. Relevant theoretical and experimental work has been carried out in the laboratory and substantiated by field trials of stress-corrosion cracking in the wing of Hercules and of fatigue cracking in the wheels of Macchi aircraft. The concept has been publicised to the local fibre-composite industry and to civil aircraft operators; currently an attempt is being made to reinforce a landing wheel on the QANTAS Boeing 747 aircraft to extend its useful life. Patching will be done in ARL and final testing will be carried out in the USA by Bendix, the results being made available to ARL. Crack patching and selective reinforcement are seen to be of great practical value. The basic ideas have been proven; wide use is likely as suitable applications are developed and are proved in operations.

25.4.41 Another area of concern is the development of non-destructive inspection (NDI) techniques to locate defects before they reach a size where the risk of an 'in flight' failure is unacceptably high. Two avenues

are available; first, the exploitation of a physical principle not previously used; and second, the development of existing techniques. As an example, some work has been carried out on acoustic emission associated with a change in the physical state of the material. Corrosion and crack growth are two examples of such a change and the technique therefore should be able to detect their progress. Early promise is being realised, and a joint US-Australian experiment using specially developed US equipment in a Macchi aircraft is planned. The Macchi is the only aircraft known to be flying with a significant crack in a critical structural member. Besides the general search for better NDI techniques, effort is devoted to 'tailoring' existing techniques to specific applications.

25.4.42 An important part of ARL's work is the direct support to the operators and airworthiness authorities when failures, or incipient failures, are detected in service, and appropriate action has to be taken. While engineers in the various organisations deal with the more straight-forward problems, ARL advice is often sought for the more complex. This work not only helps in arriving at a solution to the problem, but it also acts as a stimulus in locating general problem areas and thus defining profitable lines of research, e.g. the variability of the human operator in non-destructive inspection, the effect of water-displacing-fluids on the fatigue characteristics of bolted and riveted joints, and the need to monitor the environment for its effects on corrosion.

25.4.43 The Air Transport Group of the Department of Transport has financially supported work in ARL, CSIRO and some tertiary institutions on material problems. However, the amount of money spent in this way is small. As examples, CSIRO examined the fire resistance, flammability, and toxicity rating of the combustion products, of interior linings, seat upholstery and floor coverings of aircraft (and surface vehicle) passenger cabins. Again, the Air Transport Group is one of three contributors, each spending \$5,000 in support of corrosion work at Flinders University.

25.4.44 The Materials Research Laboratories (MRL) is playing an active part in studying the problems arising from the degradation of organic sealants such as those used in the F111 aircraft. Not only does a problem exist in repairing or replacing degraded material, but there is the possibility that the degraded material will contain chemicals promoting corrosion and crack growth. MRL is also consulted on paint problems, and on fuels, lubricants and hydraulic fluids; it played an important role in investigating and developing controls for fuel contamination by fungi.

PROPULSION

25.4.45 The propulsion system in most modern aircraft is based on the gas turbine used in jet, ducted fan or propeller form. Some reciprocating engines are used in smaller aircraft, while rockets are generally retained for short-range missiles or for use where high thrusts are required for a short time. For intermediate ranges, the propulsive duct and ram jet offer simplicity, but generally not economy; they gain over the rocket because they only have to carry fuel and not the oxidant as well.

25.4.46 Work in the air-breathing propulsion field is generally carried out at ARL while the Defence Research Centre, Salisbury is active in rocket propulsion. Some R&D which could relate to air-breathing engines is carried out in tertiary institutions, particularly Sydney, Melbourne and Adelaide universities, but there is difficulty in identifying its contribution to aeronautics in Australia. Again the Engineering Development Establishment (part of the Defence Science and Technology Organisation) is looking at alternative fuels for Otto cycle reciprocating engines. This could have some relevance to aeronautics in the long term.

25.4.47 Propulsion work at ARL generally falls into the fields basic to the study of propulsion: fluid mechanics, thermodynamics, heat transfer and combustion; mechanics related to rotors, gearing, shafting and bearings; and control systems. In addition, there is interest in the performance modelling of aircraft for mission planning and for assessment of combat effectiveness, in factors affecting the life of engine components and the monitoring of engine health and in the vulnerability of propulsion systems.

25.4.48 Overall flow characteristics in engine intakes, compressors, combustion chambers and turbines are generally dictated by the behaviour of the boundary layer. Background research is therefore proceeding on boundary layer flows, particularly where these are disturbed by steps or pressure gradients. Again, flow in the intake to the compressor is important. Brief mention of this work has been made in the section on aerodynamics.

25.4.49 Another area of broad interest is the modelling of aircraft performance. The characteristics of the propulsion system are described in some detail in mathematical terms; using simple aerodynamics and a physical description of the aircraft, the equations of motion are solved to provide an aircraft flight path for any selected condition of engine operation. By this means, it is possible to obtain such information as take-off distance, time-to-height, fuel consumption, range, optimum mission profiles. The technique has been applied to the F111 and the Mirage, and is being extended to provide data on the relative capability of the two aircraft in combat.

25.4.50 The life of engine components is important in determining the cost-of-ownership. Replacement of components is generally undertaken when many still have useful residual life. More economic maintenance procedures will result if component lives can be more accurately determined, or some monitoring system can be produced which will indicate a developing fault. Work in the latter area is proceeding to try to identify the sensitivity of various engine parameters to typical degradation processes. To gain practical experience, a Macchi aircraft has been fitted with instruments to monitor the health of the engine. Again, a gear rig and a bearing rig are being used to study the progress of component deterioration and to relate such progress to monitored data, e.g. magnetic wear particles picked up from the lubricating oil by a magnetised plug, the spectroscopic analysis of the oil to identify the composition of wear-particles, and the spectral analysis of engine vibrations.

25.4.51 Problems under investigation for the Services include amelioration of damage by foreign objects to Chinook helicopters (Lycoming T55 engine); investigation of sudden engine stoppage in flight in Iroquois helicopters (Lycoming T53 engine); deterioration of safe operating range with degraded-engine operation in F111C aircraft (Pratt and Whitney TF30 engine); propulsion aspects of the RAAF's interest in a fighter aircraft; the determination of the safe-life for the main rotor gear box in Wessex and Sea King helicopters (Rolls Royce Gislende and Gnome engines); improvement of crew environmental conditions (vibration, noise and cabin temperature) in Sea King; development of 'vibration signature' methods for determining the health (or otherwise) of engine accessories such as pumps and gear boxes.

25.4.52 Operational problems of the type described above, and the broad areas of applied research, require the maintenance and development of instrumentation, data recording and data analysis systems.

25.4.53 In addition to the above close-support type of R&D, longer range projects are in hand, notably those relating to energy sources for defence. The situation in regard to petroleum fuel has been reviewed and investigations into substitute fuels have been initiated. Factors governing the completeness and intensity of combustion both in continuous combustors and in intermittent burning processes are being evaluated.

25.4.54 The Defence Research Centre, Salisbury (DRCS) is concerned with rocket propulsion: the rocket motors for Ikara and Turana were designed and developed there in fairly close collaboration with the factories in the Department of Productivity. In addition, DRCS is often asked to advise on service problems with rocket motors; these generally relate to the degradation of the propellant, inhibitor, bonding agents or insulants when stored. Most motors have a 'safe' shelf-life which is very dependent on the temperature in the store, as temperature is a major factor in determining the rate of deterioration.

25.4.55 The development of the Murrawa motor for Ikara led to an extensive investigation into the reasons for 'ballistic drift', a change in the burning rate of the propellant. The Ikara system requires a guaranteed minimum thrust from the motor to ensure a satisfactory launch, and early experience indicated a major difficulty in controlling propellant manufacture to ensure the maintenance of the minimum acceptable burning rate with time. Long-term experiments were undertaken with exchanges of results with other countries in The Technical Co-operation Program, and these have shown that some improvement in control of ballistic drift is possible by carefully controlling moisture content during manufacture.

25.4.56 A study has also been made of the ageing of the fuel, polybutadiene, as a component of a composite propellant. As with many synthetic rubbers, the characteristics of polybutadiene change with age. The resulting loss of rubbery properties is unacceptable in propellants, and hence the need to understand the process and retard its progress. The study technique has been to examine the changes that occur in time by extracting propellant with a solvent, and injecting the extract in a gel permeation chromatograph. Important findings are the loss of volatile

plasticiser as a prime cause of propellant hardening, and the loss of an anti-oxidant leading to the start of oxidation of the polybutadiene. In one propellant which degraded unless kept very dry the problem was traced to a breakdown of the surface active agent which enabled an efficient contact to be made between crystals of ammonium perchlorate and the organic fuel; a surface active agent more resistant to hydrolysis was needed.

25.4.57 The high temperatures and high exhaust speeds of rocket motors offer quite challenging problems in materials technology and design techniques. Ablative materials are frequently used to insulate the hot gases from the pressure vessel; carbon insets are used at the exhaust nozzle throat where heat transfer is a maximum; reliable and simple ways of changing the direction of rocket thrust (thrust vector controls) are needed.

25.4.58 Research in the universities on air-breathing engines is mainly carried out in the Universities of Sydney and Melbourne. The fields covered concern the mechanism of combustion of petroleum and other fuels such as hydrogen, and studies of exhaust emissions. Fundamental studies are made at the University of Adelaide of machinery and jet noise, of noise attenuation, and on noise generation in, and radiation from, pipes and ducts.

OPERATIONAL SYSTEMS

25.4.59 The behaviour of an operational aircraft is determined by the constraints under which it operates, by the characteristics of the machine and by its control systems including man as pilot, navigator etc. The total system can be most complex, and often requires the use of the techniques of operational analysis to develop an understanding of its behaviour. Sometimes, however, it is possible to isolate a particular area of interest that falls within one of the previous broad areas of technology.

25.4.60 Studies of military operational systems are undertaken largely in the Aircraft Research and Development Unit located at Edinburgh Airfield, SA. Not only do they conduct military test flying, but they also can respond to civil needs in a similar way to the Defence Laboratories. A large part of their work is concerned with the introduction or development of new sub-systems for existing aircraft, e.g. the carriage of a new store or the checking of a new navigation system.

25.4.61 Defence Research Centre, Salisbury maintains a team to collect data, on the behaviour of particular systems during military exercises, for later analysis. The team has developed standard instrumentation packages and the range of these will obviously be increased as demands are raised.

25.4.62 Finally, it is interesting to note the development of a combined DRCS, ARL, RAAF, Department of Transport and Bureau of Meteorology program on wind shear. High wind shear, the rapid change of wind direction or strength with height, has been the cause of a number of fatal

aircraft accidents and incidents, particularly in the United States of America. The study here is aimed at:

- . identifying the severity of the wind shear problem in Australia;
- . deciding what is needed in the way of a monitoring system at affected airports;
- . developing any monitoring systems that are needed. Such a system will have to be based on a remote sensing technique since obstructions in the flight-path are obviously not acceptable.

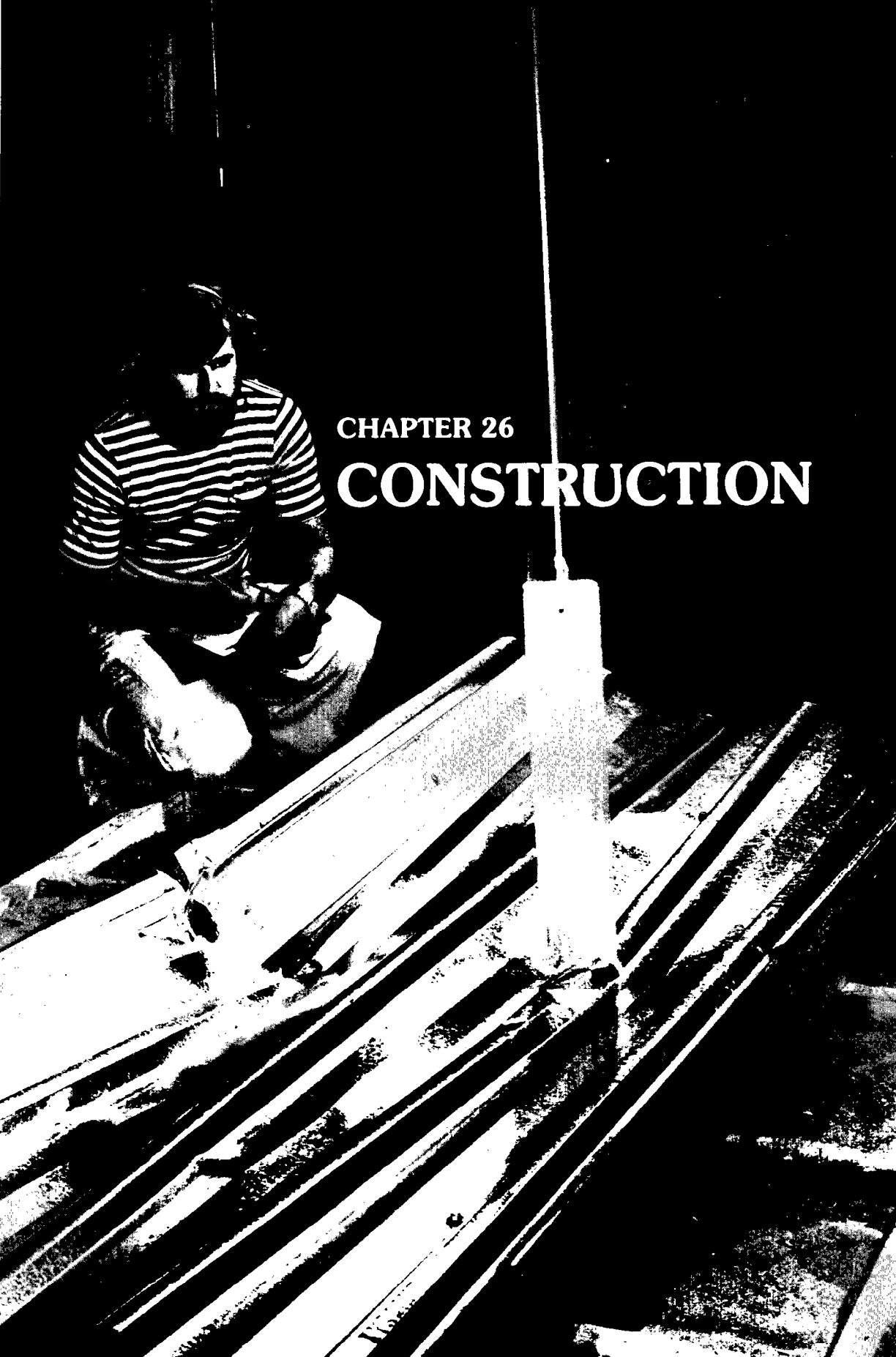
PROJECTS

25.4.63 The R&D work carried out by industry is generally related either to specific projects, often leading to some subsequent production, or to developing a capability for tackling specialised production. Of the three major aircraft factories, the Government Aircraft Factory (GAF) spends most money on R&D. This is to be expected because GAF is still actively involved with the development of Nomad, Turana, Ikara and Jindivik. In turn, these developments have made demands on Defence Science and Technology Organisation (DSTO) Laboratories, particularly ARL and DRCS. Wind tunnel testing, static structural tests, flutter mode measurements have all been carried out by ARL while GAF is conducting a structural fatigue test at ARL and under ARL direction.

25.4.64 From time to time problems being examined by the DSTO Laboratories can benefit by seeking assistance from the factories. Industry generally welcomes an invitation to consider work of this nature, especially if later manufacture might be involved. However, continuity of a workload of this type needs to be reasonably certain for industry to build up and maintain the necessary professional staff.

NOTES AND REFERENCES

1. Industries Assistance Commission 'Aerospace Industry', Australian Government Publishing Service, Canberra, 1975.
2. J.L. Watkins, 'The Airline Role in Australian Public Transport', the Lawrence Hargrave Memorial Lecture 1976, the Royal Aeronautical Society, Australian Division.
3. J. Niall, 'The General Aviation Industry in Australia', Technical Paper No. 7, Institute of Applied Economic and Social Research, University of Melbourne, 1974.



CHAPTER 26

CONSTRUCTION

Photograph: Impact testing of roof sheeting to determine resistance to debris flying in cyclones.
(Photograph courtesy CSIRO Division of Building Research).

CHAPTER 26

CONSTRUCTION

26.1 INTRODUCTION

DEFINITION OF AREA COVERED

26.1.1 The building and construction industry is considered to cover the planning, design, construction and maintenance of products static on the earth's surface (floods, cyclones and earthquakes permitting). The products are generally expected to have a long life.

26.1.2 In the Australian National Accounts [1], Construction includes all establishments engaged in constructing buildings, roads, railroads, aerodromes, irrigation projects, harbour or river works, water, gas, sewerage or stormwater drains or mains, electricity or other transmission lines, pipelines, oil refineries, or other civil engineering works. Establishments mainly engaged in the repair of buildings or other structures are also included, as are those engaged in alterations and renovations, preparation of mine sites, demolition or excavation and the organisation or supervision of these kinds of work. However, establishments engaged mainly in providing architectural and engineering consultant services are included under Finance, Insurance, Real Estate and Business Services. Most sub-contracting services would appear to be included under Construction but there are some notable exceptions. In order to avoid overlapping with Chapter 35 on Transport, road construction has been excluded in this paper. Where possible, an estimate of expenditure on roads and road maintenance has been deducted from figures for expenditure on Construction.

26.1.3 This listing adequately covers the end-products of the construction industry: they are the outcome of a very large number of more basic steps in manufacture, design, supply and so on; these more basic elements are the ones to which most research effort is attached. There are some discrepancies between the construction industry, as it is recognised in published figures relating to its place in the national economy; and the industry served by the research reviewed. Every attempt has been made in this report to minimise the effect of these discrepancies.

26.1.4 In what follows, the building and construction industries as defined above have been extended to include functions or operations that directly influence decisions made in one of the four core areas of construction, namely planning, design, construction and maintenance. Such functions include anything which alters the properties, and not merely the price, of materials used.

26.1.5 Two points must be emphasised strongly; first, that no research can be identified as applying uniquely and solely to building and construction, or to any other sector, and secondly that this report will be concerned with those projects that are considered to relate mainly to building and construction, but may at the same time have substantial relevance elsewhere. Subjects which lie mainly outside the direct influence of the design-construction core are excluded, even though they may have some relevance. Thus urban planning is included, but regional planning and transport, including road construction, is not.

26.1.6 Nothing in the concept, as it has been developed, excludes social science projects; this is intentional. Information arising from studies in the social sciences can influence design decisions, particularly for housing, and therefore it is appropriate that such studies be included as research for the construction industry.

26.1.7 It is also necessary to define research. Throughout this report the term research will be used to cover the whole spectrum of activities ranging from fundamental or pure research through applied research and development, unless any specific qualification to the contrary is made. The Project SCORE [2] and OECD definitions of Basic and Applied Research and Experimental Development are used, feasibility studies being included with Applied Research and policy-related studies being regarded as a particular kind of Experimental Development. When the aim has been to compare relative levels of research in different sectors Project SCORE figures have been used.

SIZE OF THE INDUSTRY

26.1.9 Some measure of the size of the construction industry is necessary to establish the need for research and to compare this need with that of other industries. One of the main purposes of research is to raise the efficiency of an industry. There would be little to be gained by spending great effort to raise the productivity of an industry representing only a tiny sector of the economy while, on the other hand, for an industry which dominated the national economy any small improvement could be of substantial benefit.

26.1.10 The aim here is to compare the construction industry with other recognised sectors of the national economy in such matters as its contribution to gross fixed capital expenditure, gross domestic product, and operating surplus. The figures used are taken from Australian National Accounts for 1974-75. The basic data are set out in Tables 26.1, 26.2, 26.3 (which are derived from Tables 24, 17 and 20 of the document cited). From the latest figures in Table 26.1, for Wages Salaries and Supplements, it appears that Construction is the fourth largest of the eleven divisions listed. However, the figure for Construction is an underestimate in terms of the concept of the building industry given above because it does not include payments in relation to design services (architects, engineers etc.).

26.1.11 If it is assumed for the present purposes that architects and other professional designers are not used for design of houses, but only for other buildings, an estimate of the cost of the design labour can then be obtained by taking 10% (the design fee) of the value of all buildings other than dwellings. This would add \$559million to Wages etc. for Construction in 1974-75 giving a total of about \$3,160million. This does not alter the ranking of the sectors on a Wages basis.

TABLE 26.1

TOTAL WAGES, SALARIES ETC. PAID BY INDUSTRY
1971-72 to 1973-74
(\$million)

	<u>1971-72</u>	<u>1972-73</u>	<u>1973-74</u>
Agriculture, Forestry, Fishing etc.	430	478	591
Mining	459	506	602
Manufacturing	5,592	6,143	7,526
Electricity, Gas and Water	502	558	675
Construction	2,064	2,233	2,597
Wholesale and Retail Trade	3,055	3,452	4,242
Transport, Storage, Communication	1,671	1,870	2,383
Finance and Business Services	1,526	1,756	2,151
Public Administration and Defence	1,523	1,724	2,115
Community Services	2,570	2,929	3,656
Entertainment and personal	676	768	980
Total	<u>20,068</u>	<u>22,417</u>	<u>27,518</u>

TABLE 26.2

GROSS DOMESTIC PRODUCT AT FACTOR COST, BY INDUSTRY
1971-72 to 1973-74
(\$million)

	<u>1971-72</u>	<u>1972-73</u>	<u>1973-74</u>
Agriculture, etc.	2,302	2,992	4,325
Mining	1,338	1,427	1,667
Manufacturing	7,960	8,875	10,480
Electricity, etc.	1,157	1,298	1,462
Construction	2,764	3,042	3,465
Wholesale and Retail	4,912	5,661	6,787
Transport, etc.	2,700	2,915	3,450
Finance, etc.	3,042	3,661	4,307
Public Administration, etc.	1,523	1,724	2,115
Community Services)			
Entertainment, etc.)	4,028	4,590	5,663
Ownership of Dwellings	<u>2,165</u>	<u>2,484</u>	<u>2,929</u>
Total	<u>33,891</u>	<u>38,669</u>	<u>46,650</u>

TABLE 26.3

GROSS OPERATING SURPLUS OF TRADING ENTERPRISE COMPANIES
BY INDUSTRY OF ESTABLISHMENT

1971-72 to 1973-74

(\$million)

	<u>1971-72</u>	<u>1972-73</u>	<u>1973-74</u>
Agriculture, etc.	81	141	212
Mining	836	885	1,026
Manufacturing	2,104	2,431	2,595
Electricity, etc.	27	22	19
Construction	195	206	173
Wholesale and Retail	1,038	1,267	1,457
Transport, etc.	234	255	298
Finance, etc.	383	533	630
Community Services)			
Entertainment, etc.)	183	213	245
Ownership of Dwellings	<u>27</u>	<u>31</u>	<u>35</u>
Total	<u>5,098</u>	<u>5,984</u>	<u>6,690</u>

26.1.12 In other sectors the listed figures for Wages etc. do not provide a complete measure of the value of labour involved in the total production. This is particularly true of Agriculture where no notional allowance is made for the work of farmer-proprietors and of members of his family. Again it is possible to compensate approximately for this omission.

26.1.13 In the Australian Bureau of Statistics publication 'The Labour Force' [3], the total employment in each sector at February 1974 including employers and self-employed persons is as shown in Table 26.4

TABLE 26.4

<u>Industry</u>	<u>Number of Employed Persons</u> <u>February 1974 ('000)</u>
Agriculture	373.5
Manufacturing	1,360.2
Construction	518.4
Wholesale and Retail Trade	1,177.5
Transport and Storage	303.3
Finance, etc. and Business Services	414.8
Community Services	718.3
Entertainment, etc. and Personal Services	357.1
Other Industries	547.0

26.1.14 Dividing the Wages etc. for each sector for 1973-74 by the corresponding figures in Table 26.4 gives the 'average' wage in each sector, as in Table 26.5.

TABLE 26.5

<u>Industry</u>	<u>Wages paid per Employed Person</u>
	<u>1973-74 (\$)</u>
Agriculture	1,582
Manufacturing	5,533
Construction	5,010
Wholesale and Retail Trade	3,603
Finance, etc.	5,186
Community Services	5,090
Entertainment, etc.	2,744

26.1.15 Four of the sectors lie close together over \$5,000, which is also reasonably close to the overall average male wage of \$5,891 for the March quarter of 1974. However, the average wages in Table 26.5 for Agriculture and for Wholesale-Retail are lower than the overall average, Agriculture being much lower. These two sectors are those in which the unpaid work of proprietors and their families in small units of operation can be expected.

26.1.16 It is suggested then that more appropriate estimates of the Wages costs can be obtained for Agriculture by multiplying the figure in Table 26.1 by 3.3 and for Wholesale-Retail by multiplying the figure by 1.44. These multipliers are the ratios of the average wage (\$5,205) of the four sectors over \$5,000 and the figure given in Table 26.5 for the sector.

26.1.17 After these modifications, the final column of Table 26.1 now becomes that given in Table 26.6.

TABLE 26.6

	<u>Notional Wages etc.</u>
	<u>(\$million)</u>
Agriculture	1,950
Mining	602
Manufacturing	7,526
Construction	3,160
Wholesale and Retail	6,108
Transport etc.	2,383
Finance and services	2,151
Public administration and defence	2,115
Community services	3,656
Entertainment	1,862

26.1.18 Table 26.7 is derived from the figures for 1974-75 in Tables 26.2, 26.3 and 26.6. The first three columns give a further measure of the size of other sectors compared to Construction; the Wages, Salaries etc. total, the contributions to the GDP and the Gross Operating Surplus (GOS) for each sector are each divided by the corresponding figure for Construction.

TABLE 26.7

COMPARISON OF CONSTRUCTION WITH OTHER INDUSTRY GROUPS

	(1) Wages Ratio	(2) GDP Ratio	(3) GOS Ratio	(4) GDP Wages	(5) GOS Wages
Agriculture	0.62	1.25	1.23	2.22	0.109
Mining	0.19	0.48	5.93	2.77	1.70
Manufacturing	2.38	3.02	15.0	1.39	0.34
Wholesale and Retail	1.93	1.96	8.42	1.11	0.24
Transport etc.	0.75	1.00	1.72	1.45	0.13
Construction	1.00	1.00	1.00	1.10	0.055

26.1.19 The conclusions to be drawn from Table 26.7 are:

- (a) In terms of wages paid only Agriculture and Mining are substantially smaller than Construction; Manufacturing and Wholesale-Retail are substantially larger (Col. 1)
- (b) Only Mining made a smaller contribution to the GDP than Construction (Col. 2)
- (c) Construction had the smallest Gross Operating Surplus (GOS) (Col.3)
- (d) Agriculture and Mining are apart from the other industry groups in having much more value added to the GDP for each dollar of wages (Col.4)
- (e) The ratio of GOS to wages gives a rough guide to the profitability of an industry and hence of the funds from which research support might be drawn. The very low ratio for construction is notable (Col.5).

26.1.20 The picture which emerges from this admittedly brief review is that Construction is one of the large industries of the economy, but one which may appear seriously inefficient by some measures. By the indicators used, the closest parallel is Transport and Communication. On the basis of value added to the GDP per dollar of wages Agriculture is about twice as effective as Construction. Again each dollar of Wages etc. in Construction yields a Gross Operating Surplus of about six cents as against \$1.70 for Mining.

26.1.21 Expressed another way, if the wages dollar in Construction was as effective in producing added value as in Mining, the same output could have been achieved for about half the wages bill. Such an increase in performance could not be achieved without a very substantial research input. So long as the operating surplus in the Construction industry remains so low it is unlikely that this research could be funded by the industry itself.

ORGANISATION

26.2.1 The construction industry is a large and diverse entity with many facets and there is a correspondingly large number of committees and organisations charged with reviewing and co-ordinating research in different segments of the industry. This Chapter is mainly based on the records established by these committees. An attempt to identify the functions of the numerous committees and organisations that participate in research for building and construction now follows.

26.2.2 CSIRO. Three divisions of CSIRO do some research relating to construction:

- . Division of Building Research (DBR)
- . Division of Mechanical Engineering (DME)
- . Division of Applied Geomechanics (DAG)

26.2.3 Commonwealth Department of Construction. This Department is responsible for the construction of works and services for the Commonwealth Government. A large amount of development and applied research is done throughout its Central and Regional Offices; experimental research, mainly in the service of the Department, is done at two laboratories, the Experimental Building Station (EBS), and the Central Investigation & Research Laboratory (CIRL)

26.2.4 Building Research and Development Advisory Committee (BRDAC). This is the main link between private industry and the principal Commonwealth research units, the CSIRO Division of Building Research, the Department of Construction, and the Physical Working Environment Branch of the Department of Productivity. It has a membership of five officials from the organisations covered, seven members from private industry or higher education and a secretary provided by the Department of Construction. Its terms of reference are:

- . To advise the Commonwealth Government organisations concerned in building R&D on the technical problems of industry, and to draw attention to research, investigation, development work or technical liaison activity required.
- . To assist in the dissemination of knowledge of the activities of organisations undertaking R&D.
- To investigate the nature and extent of both government and privately funded research in the Australian building industry and to advise all parties concerned of any overlapping or duplication of research effort.

To report annually to the Minister for Construction on the above.

26.2.5 Building Research Committee (BRC). This covers the same area of research as BRDAC but its members are the senior officers of the CSIRO Divisions of Building Research, Mechanical Engineering, and Applied Geomechanics; the Divisional and Branch Heads from the Technology Division of the Department of Construction; and the Head of the Physical Working Environment Branch of the Department of Productivity. The secretary is provided by the Division of Building Research. The terms of reference are:

To review the research program proposed by each organisation participating in the Committee's activities.

To prepare for the advice of each participating organisation a research program, taking into account the recommendations of the Building Research and Development Advisory Committee of the Department of Construction.

26.2.6 Australian Housing Research Council (AHRC) and its Research Advisory Committee (AHRAC). The AHRC comprises the Ministers for Housing from each State, with the Commonwealth Minister as Chairman. The Research Advisory Committee comprises senior officers of each State Housing Authority and from the Northern Territory Housing Trust, together with nominees of the Chiefs of the CSIRO Division of Building Research, and of the Experimental Building Station. The Chairman and Secretariat are provided by the Commonwealth Department of Environment, Housing and Community Development. The AHRC is financed by State and Commonwealth Governments, and it allots research contracts to other bodies. The terms of reference are:

To provide for research into those aspects of housing of particular concern to the Government sector, and for development of new techniques and methods resulting from that research.

To provide for the dissemination to interested groups and individuals of information gained through the sponsored research projects.

To foster collaboration in the conduct of research projects between organisations carrying out housing research, including governmental, non-governmental and overseas bodies.

To foster applied R&D in the field of government housing. The primary objective is to assist State and Commonwealth Governments to ascertain, develop, provide and manage the most appropriate forms of government housing.

To complement R&D work already being carried out by government agencies, universities and other

organisations and in general to stimulate new work which cannot reasonably be expected to be handled within existing programs of those agencies.

26.2.7 National Public Works Conference, and its Research Co-ordinating Committee (NPWC/RCC). The Conference comprises the Permanent Heads of all State and Commonwealth Public Works authorities. The Research Co-ordinating Committee draws its members from the senior officers responsible for research in each Department with an Assistant Chief from CSIRO/DBR as Chairman. It maintains a register of research activities of its members.

26.2.8 Australian Engineering and Building Industries Research Association (AEBIRA). A voluntary organisation drawing its membership from private industry and the Department of Construction. It solicits funds for the support of specific projects for which it allots contracts.

26.2.9 National Committee on Rationalised Building (NCRB). All public works authorities, State housing authorities, Commonwealth Department of Transport, Telecom, the National Capital Development Commission and CSIRO/DBR are members of this committee which provides a forum for multidisciplinary discussion by all government construction and research agencies. Its main function is becoming the exchange of experience related to development.

26.2.10 It should be noted that, of the eight bodies listed above only two, the CSIRO and the Department of Construction, actually conduct research for construction.

26.2.11 Besides these groups which deal specifically with research for construction there are others which cover construction research within general overviews of scientific and industrial research. Foremost among these is Project SCORE. The present report leans heavily on the basic work of Project SCORE and may be regarded as an amplification and interpretation of that work with respect to Construction. Some other organisations, from which relevant information has been obtained, are:

- . The Australian Bureau of Statistics (ABS)
- . Australian Research Grants Committee (ARGC). This is the funding committee for some of the research done in universities and colleges of advanced education. Generally, but not exclusively, it supports basic research.
- . Australian Industrial Research and Development Incentives Board (AIRDIB). This Board serves a purpose for the Business Enterprise sector somewhat analogous to that of the ARGC. Details of the projects supported are confidential but the Board provided aggregate figures for expenditure on work related to materials and products in the building industry.

Central Information, Library and Editorial Section (CILES) - CSIRO. CILES has produced a register of Scientific and Technical Research Centres in Australia, which provides a ready guide to places engaged in any technical research related to building, together with the number of staff so employed.

The Institution of Engineers, Australia (IEA). Useful confirmatory information has been obtained from surveys carried out by the National Committees of the Institution.

FUNDING

26.2.12 The assessment of the total expenditure on R&D for construction is based on the work of Project SCORE. The information presented here therefore is very largely an updating and extension of Project SCORE and an examination in slightly greater detail. In Project SCORE terms the Gross Expenditure on Research and Development (GERD) for 1976-77 was \$0.9million but was actually nearer \$1.2million when somewhat broader definitions are used; the latter figure has been used here. Other figures not supplied to Project SCORE have been included here. Thus \$1.4million represents the R&D effort in the Central Office and Regions of the Department of Construction.

26.2.13 It is inevitable that a survey of this sort must underestimate the total R&D effort of the community. For instance, studies undertaken in government departments or elsewhere in relation to some specific project may well be found to have wider relevance and therefore should be more properly regarded as R&D. Two factors here will partly compensate for this underestimate: the first is the similar inevitability of a certain amount of double counting, and the second is an apparent over-compensation in the multipliers used to bring all figures to a common base year. The former is hard to eliminate.

26.2.14 In order to bring all monetary items to a common base year ASTEC obtained from the Australian Bureau of Statistics the following set of multipliers for the base year 1976-77 as in Table 26.8.

TABLE 26.8

<u>Year</u>	<u>ABS Based</u>	<u>CSIRO/DBR</u>
1970-71	2.29	1.82
1971-72	2.05	1.75
1972-73	1.90	1.59
1973-74	1.63	1.40
1974-75	1.30	1.27
1975-76	1.11	1.07
1976-77	1.00	1.00

The figures in the third column show the actual variation in expenditure estimated by the CSIRO Division of Building Research. From this comparison it appears that the ABS-based figures over-compensate for

inflation, although the extent of this over-compensation is not established because other factors, such as staff levels, changed in CSIRO/DBR in the period under review. The ABS-based multipliers have been used in compiling Table 26.9 below.

26.2.15 The ultimate result of this review of expenditure on R&D is shown in Table 26.9. The year of the actual figures and the multipliers used are shown. The total expenditure for construction R&D arrived at for 1976-77 is \$15.792 million. Of this total CSIRO/DBR provides about 25%, the Department of Construction 20%, and private industry altogether 24%. This total expenditure, reduced to 1974-75 terms is rather less than 0.2% of the output of the industry even after removing expenditure on roads. While construction contributes nearly 8% of the value of Gross Domestic Product, research in this sector constitutes about 1.9 % of gross expenditure on R&D. By comparison, a survey in 1972 by the Department of Manufacturing Industry found that expenditure on research and development in the Manufacturing Sector was nearly 2% of output and the figures from Project SCORE 1973-74 suggest that the proportion for Agriculture is over 1%. It must be noted that throughout this discussion expenditure on R&D is confined to operating expenditure and no attempt has been made to examine capital expenditure on building and facilities.

26.2.16 Although the various estimates of gross expenditure on R&D show considerable differences it is believed that Table 26.9 illustrates the relative importance of the different sectors with adequate accuracy.

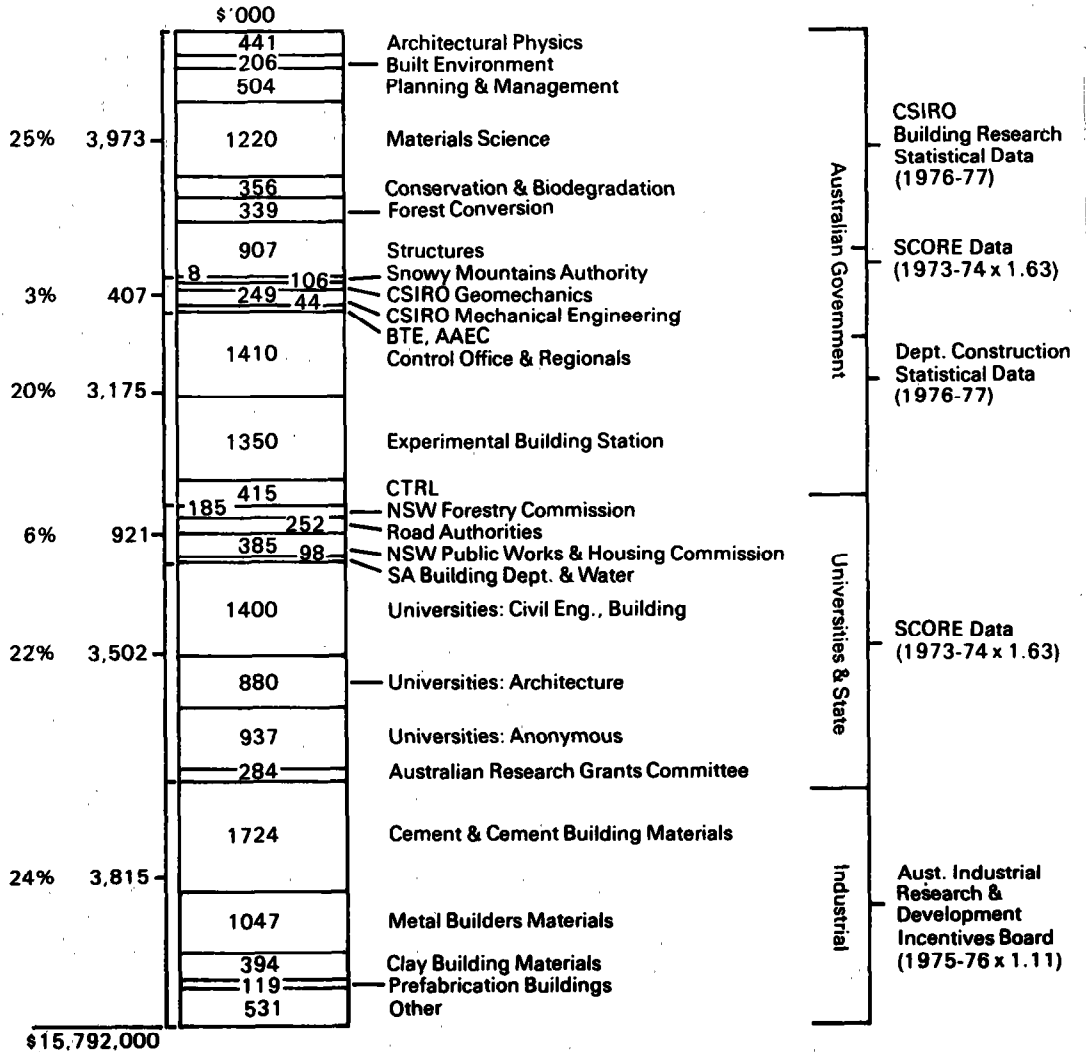
26.3 RESEARCH AND DEVELOPMENT

FACTORS INFLUENCING R&D

26.3.1 We now consider what characteristics, other than the economic indicators, might exercise an important influence on the level of R&D for the industry. Perhaps the first attempt to study the construction industry, as it actually works, was made by the Tavistock Institute in 1966 [4]. As expressed in the title of their report, they saw the characteristics as interdependence and uncertainty. It is proposed here that this uncertainty arises from the extreme complexity, fragmentation and uncontrolled interaction of the industry.

26.3.2 By contrast with the way in which manufacturing industry functions, the end products of construction are nearly always 'one-off' products, not one of a series. There have been persistent endeavours to make dwelling construction into a production operation but in Australia this has never succeeded completely; if for no other reason than that each site is different, some differences in the end products are inevitable. The team

TABLE 26.9
1976-77 R&D EXPENDITURE IN AUSTRALIA ON THE
CONSTRUCTION SECTOR



CTRL Central Testing and Research Laboratory

of designers, builders, financiers etc. who come together to produce this single product have often not worked together before and may never work together again; in such a situation there is little incentive to innovate. There is no opportunity, through continued use, to examine the modifications that must be made to any innovation before it can be fully effective and there is no incentive for anyone to make such an examination because there is no single point of responsibility which could benefit from such a study.

26.3.3 In Australia the practice of sub-contracting all parts of the construction operation has probably gone further than in any other country, especially for dwelling construction. While this has had advantages in raising productivity [5] it has done so within the limits of existing technology. It has also created a situation where the major contractor has no need to concern himself with technological changes, and where the sub-contractors do not have the resources with which to make innovations.

26.3.4 The practice in the construction industry of sub-contracting at several levels, coupled with the use of an increasing number of specialist design consultants, leads to a fragmentation of the industry which is quite distinctive. This fragmentation creates a large number of interfaces at which decisions have to be made, usually on the basis of cost. There is no evidence that the union of all these decisions will lead to an optimum for the whole operation. Some quantitative evidence of the increase in cost produced by sub-contracting is given by Solomon [6].

26.3.5 The current state of fragmentation is a logical evolution in response to technological changes, and has generally been to the advantage of all individuals involved. However, the fragmentation has created problems for the industry as a whole so that the greatest problem now lies in co-ordinating and controlling all the fragments to achieve an efficient, overall, production process.

26.3.6 The fragmentation of organisation both in design and construction has highlighted the importance of the interfaces between the different operations, and the lack of fit which can occur. To say that it is the job of the contractor or project manager to ensure that there is no lack of fit at the interfaces may well be legally correct but that does not remove the problem. The problems still remain of reconciling the requirements of the acoustic design with the design for thermal comfort, or of achieving an economic location of all services, while providing access for maintenance, but not interfering with fire barriers or the integrity of joints in the structure.

26.3.7 The basic theories of the technologies used in construction have now been well established for some 50 years and the basic craft processes are much older. The changes which have taken place recently are in materials and in the aids of computation. The state has now been reached at which almost any problem within a particular discipline can be solved if the boundary conditions, such as loads, temperatures, and the properties of the materials are known. Established theories and powerful computational tools now demand a high degree of realism in specifying levels of load,

temperature, noise intensity and so on if the results of the calculations are to be relevant to the daily use of the structure. The degree of knowledge of these levels, which may be regarded as the interface of the design theory with the real world, is by no means as great as that of the properties of materials or of the basic theory itself.

26.3.8 This view of the development of the various technologies in construction can be summarised by saying that, with few exceptions, the basic theories themselves, and the knowledge of materials, are now adequate for practical purposes. This assertion is admittedly a practical one which would probably not be supported by those engaged in fundamental research. However, with the possible exception of plastics, there is little evidence of any direct influence of recent fundamental research on the construction industry.

26.3.9 It is difficult to provide any quantitative measure of the significance of the fragmentation of the industry on its performance but the following evidence may be considered relevant. In his studies of contract time-cost performance, Bromilow [7] found that variations to contracts generally added about 10% to the contract sum. The client and the architect initiated the majority of these variations. In theory therefore, elimination of variations would save 10% of building costs. In a major commercial building the structural engineering component accounts for only about 20% of total cost and all mechanical and electrical services for about 40%. It is hard to conceive of any changes in either of these major components which could lower the building cost by 1%.

26.3.10 Again, Bromilow's studies have demonstrated the relative cost of time in design and in construction. In major projects the overriding requirement is for rapid construction even at the expense of less than optimal use of materials. Delays resulting from inadequate detailing, or by failure of individual operations to start and finish at the expected times, or by failure of suppliers to deliver components, to the right specification at the right place and time, all have serious effects on the cost of construction. Labour troubles, which have seriously disrupted many construction programs in recent years may be particularly serious. Such troubles, however, may also be regarded as merely one aspect of current political conflicts, not peculiar to the building industry. Difficulties of the same sort no doubt arise in other industries but, because of the temporary nature of the construction site and of the whole production team, it is inevitable that their effect will be much more disruptive than elsewhere.

26.3.11 In an attempt to overcome some of these difficulties there have been, in recent years, an increasing number of non-conventional contracts, which have been let on some other basis than open tender. These range from various forms of selected tendering to negotiated contracts, package deals and the like. It is hardly surprising that negotiated contracts have been found generally superior on a time-cost basis [8]. This form of contract is appreciated by clients because it provides a single point of responsibility in all negotiations; the plethora of designers, consultants, contractors, subcontractors and suppliers is avoided. The efficiency of such a system has been recognised in the

adoption of project management organisation within the Department of Construction and its favourable acceptance by clients of the Department.

26.3.12 Another aspect of the complexity of the building industry is that of the regulations under which projects are carried out. In Victoria there are twenty-eight Acts of Parliament under which it is possible to make regulations affecting the construction and use of buildings, quite apart from planning, development, or environmental requirements. This complexity is further compounded because there is not a central point of reference in any State where information about this multitude of regulations can be obtained; the delays involved in seeking this information and in awaiting permission from the various authorities can be extremely costly.

26.3.13 Characteristics of the labour force also distinguish the construction industry. Solomon [6] concluded that 'It has been shown that the building industry has unique problems with respect to the use of manpower resources...'. He went on to identify the special features of the industry as:

- . the industry is subject to unusually wide fluctuations in activity;
- . the workforce has a high rate of labour turnover and mobility;
- . the industry is highly labour and skill intensive; and
- . the industry has relied heavily on migrants to make up the shortfalls of locally trained workers.

26.3.14 It is claimed that skilled labour comprises 65% of the workforce used in construction as against less than 20% averaged over all industry. Over the period 1961-71 wages, salaries, etc. in construction were about 75% of the value of production as against about 66% in manufacturing and less than 60% over all industries.

CURRENT RESEARCH

26.3.15 One aspect of research, sometimes overlooked, is the question of availability and accessibility. According to Project SCORE 63% of all research in Australia (not only for construction) is funded by the taxpayers and at least that proportion of the results should be generally accessible. Three groups have a policy to publish the results of all studies; these are CSIRO, the Experimental Building Station and the higher education sector. These groups together cover just over half (56%) of the total expenditure. Nearly half the work done is not generally accessible. One of the groups which hitherto has not made any detailed disclosure of research activities comprises the Public Works Departments, or equivalent, of the States and the Commonwealth. In the business enterprise sector, some information is undoubtedly exchanged through

trade associations, and the like, but in the nature of private enterprise such exchanges must be very general if they are not to affect the competitive positions of the individual companies. In the past when problems have arisen such as expansive bricks, shrinking aggregate, cracking glass etc. each firm involved, or likely to be involved, has spent considerable effort trying to solve the problem on its own, and there has been very substantial duplication of effort.

26.3.16 Another very clear characteristic of the research scene is the big difference in concern shown by the States and the Commonwealth: the latter is estimated to spend more than four times as much as the States including their Housing Authorities. By comparison the total value of all State construction is greater than that of the Commonwealth.

26.3.17 Assessment of current research work must be related to the definitions and characteristics of the industry identified above. The most salient of these were:

- . fragmentation in organisation and responsibility;
- . complexity and diversity in the disciplines, trades and operations involved; and
- . the most commonly used materials and disciplines have been the subjects of long and profound research and have shown few basic changes in the last half century.

26.3.18 With the aid of some rather crude assumptions and oversimplifications Table 26.10 has been drawn up.

TABLE 26.10
EXPENDITURE (\$million)

<u>Basic Research</u>		<u>Applied Research</u>		<u>Development</u>	
Universities	3.501	CSIRO/DBR	2.684	Bus. Ent.	3.815
CSIRO/DBR	0.757	EBS	1.350	CSIRO/DBR	0.532
Other CSIRO	0.106	Other CSIRO	0.249	Com. Const.	1.825
		AAEC	0.052	State Const.	0.920
	4.364 (28%)		4.335 (27%)		7.092 (45%)

26.3.19 The justification of the proportion of basic research must be questioned in the light of the characteristics of the industry outlined above. It was claimed there that the basic disciplines, technologies and materials were well established and that extensive research had made very few major changes in the past 50 years.

26.3.20 In the universities and the two major Commonwealth institutions the projects can be classified as those related to security (safety of structures, fire protection, insect attack etc.); quality of life (thermal and acoustic comfort, staining and paintwork, privacy and so on); and productivity. The studies related to productivity account for roughly \$0.5million or about 3% of the total expenditure for construction R&D.

26.3.21 A notable deficiency seems to exist in the nature of the research work in that, while the efficiency of the construction sector compares unfavourably with other sectors of the economy, only a very small fraction of the research expenditure is directed at improving this efficiency or productivity. This is not to suggest that any of the current research not directed towards productivity is not needed, but it can be claimed that the productivity of the industry, which is of overriding national importance is being quite inadequately covered by research.

26.3.22 Although the Commonwealth plays a much larger part in research in the construction area than the national government in other countries, there is no justification for reducing Commonwealth involvement. First, the overall level of research is so low by comparison with other sectors, such as agriculture or manufacturing, that no reduction can be justified; secondly, staff reductions in the two leading institutions have already left major items of equipment, sometimes the only examples in Australia, grossly under-utilised; and thirdly, the general accessibility of these centres makes them the only sources of research for all the small units in the construction industry. These small units include most design and consulting offices and all local government. It is relevant to record that the CSIRO Division of Building Research and the Experimental Building Station between them answer some 50,000 enquiries each year; this number is rising and is imposing a heavy strain on existing resources.

26.3.23 It is recognised that the desirable increase in construction research should take place mainly in the State area where the greatest deficiency appears to exist. Stimulation of this sector could be linked with an effort to redirect research towards improved productivity in the industry. Public Works Departments, State Housing Authorities and other instrumentalities usually have responsibility for all stages of the construction process from planning and design, through construction, to operation and maintenance. They alone are in a position to exercise some influence and to impose some co-ordination on the grossly fragmented industry. However, there must be a requirement that any results arising from research in the State sector should be publicly available.

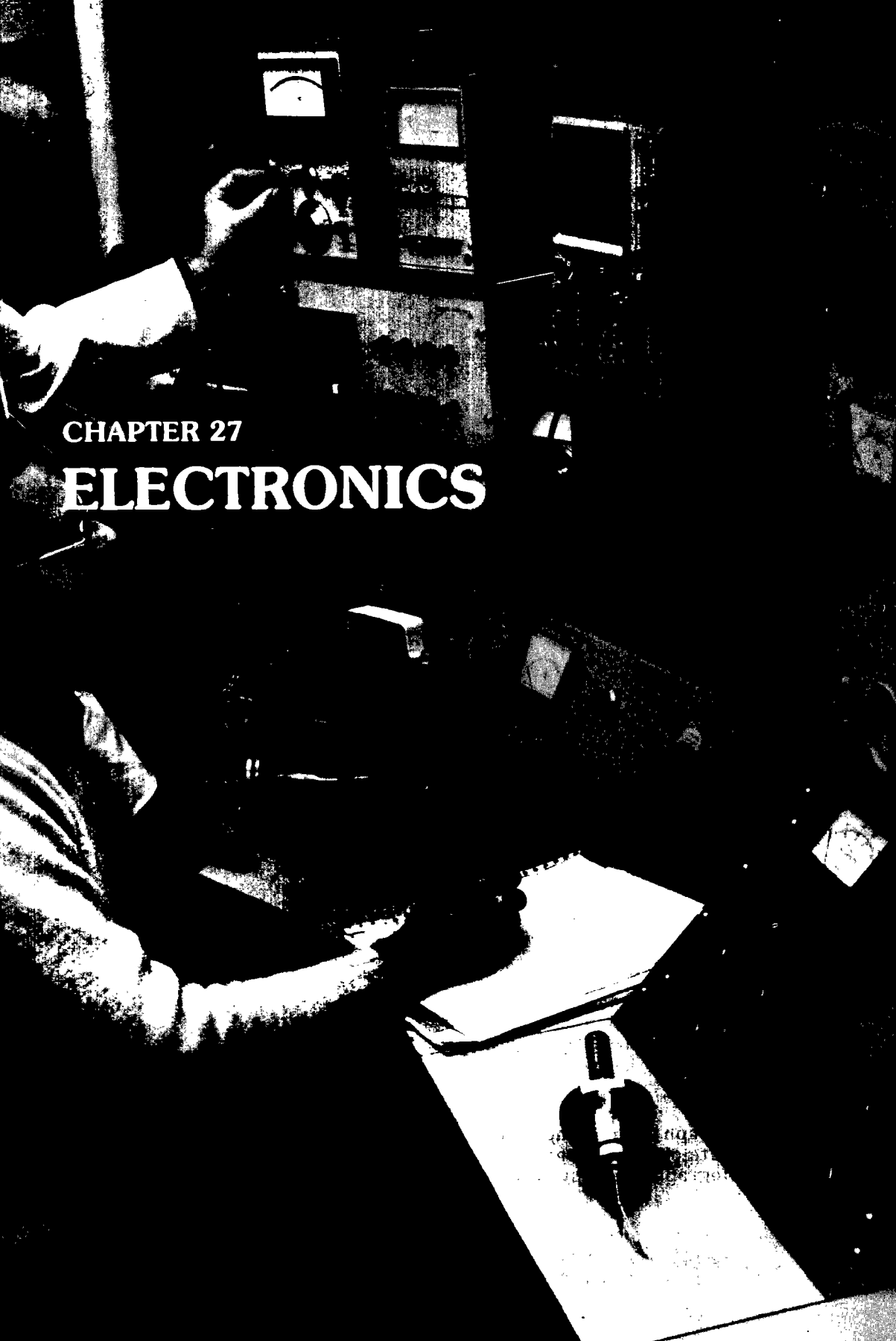
26.3.24 It is implied in any concept of improved efficiency of the industry that the lifetime cost-in-use of its products should be minimised, and this requires that continuing maintenance, a labour-intensive operation, should be reduced. Government works authorities, and the like, are in the best position to establish how the cost-in-use of any structure can be reduced.

26.3.25 In the private sector of construction a building or house is usually valued at its cost of construction; if this is low, there may have

been a transfer of high maintenance and operating costs to the purchaser. In the commercial scene this is encouraged by taxation concessions on maintenance and this means that the inefficiency of the industry is supported by the public purse.

NOTES AND REFERENCES

1. 'Australian National Accounts' (Ref. No. 7.1) National Income and Expenditure 1974-75. Australian Bureau of Statistics, Canberra, 1976.
2. Project SCORE; 'Research and Development in Australia 1973-74', vols. 1 and 2, Aust. Govt. Publishing Service, Canberra 1976.
3. 'The Labour Force' (Ref. No. 6.20), Australian Bureau of Statistics, Canberra, 1974.
4. 'Interdependence and Uncertainty: A Study of the Building Industry', Tavistock Publications, London, 1966.
5. F.A. Blakey, 'Housing Australia -Tomorrow', National Housing Builders Conference, NSW Builder 6, 1977, p245.
6. S.H. Solomon, 'Manpower resources in the building industry.' Proc. Fifth Australian Building Research Congress, Melbourne, 1975.
7. F.J. Bromilow, 'The nature and extent of variations to building contracts' Building Economist 9 (1970), 93.
8. F.J. Bromilow, 'Contracts as waste generators.' Building Forum 3 (1971), p5.



CHAPTER 27

ELECTRONICS

Photograph: Ion implanter, used for research at the Royal Melbourne Institute of Technology into new methods of electronic device fabrication. (Photograph courtesy Royal Melbourne Institute of Technology)

CHAPTER 27

ELECTRONICS

27.1 INTRODUCTION

DEFINITION OF AREA COVERED

27.1.1 Of all technological areas, electronics is perhaps the most diverse. Electronic methods have major advantages for measurement, for the storage, processing and transmission of information and above all in computing; they are finding increasing use in a rapidly widening range of applications. R&D concerned with the application of electronics in new ways and to new areas therefore extends throughout science and technology.

27.1.2 Another aspect of the diversity of electronics is the range of devices which may be classified as electronic. Where once there was only a handful, now several new products are added to the range every week. The new or enhanced properties of these devices provide opportunities for the development of equipment and systems which, in turn, extend the range of application.

27.1.3 As a direct consequence of the unique diversity of electronics there is a corresponding diversity in the type, orientation and size of organisation in which electronics R&D is undertaken. These organisations include the traditional centres of research such as government laboratories, academic institutions and large scale manufacturers of electronic components and equipment. They also include many smaller companies which develop new uses for electronic equipment in particular areas, or which exploit the capability of newly available electronic devices for particular uses. Added to these are the organisations whose primary interest is other than electronics, but who use electronic systems to the extent that they carry out R&D in the application of electronics to their field. Telecommunications, health, transport and manufacturing industry are only some of the areas in which such organisations are found.

27.1.4 In general the emphasis of electronics R&D in Australia is heavily toward experimental development. However, its wide range causes a particular problem when it comes to providing a comprehensive survey in a report such as this. In covering the spectrum of electronics R&D, research directed toward such fields as health, transport, agriculture, aerospace, etc., is dealt with in the chapters on those areas. There are also chapters on telecommunications and computing, and the remainder of electronics is covered by this chapter. In collecting material for this chapter an attempt has been made to remain within the defined scope, but at times some overlap could not be avoided.

POLICIES AND AGREEMENTS

27.2.1 There is no government body concerned with policy development and co-ordination for electronics. This contrasts with fields such as health and agriculture. It is difficult to find explicit policies or agreements of a general nature, relating to electronics.

27.2.2 A particular case in which a government body nevertheless has made specific policy recommendations relating to electronics is that of tariff protection in relation to development electronics R&D. The IAC, when reporting on 'Telecommunications Equipment' [1] took the view when considering R&D that:

The long term future of the professional electronics industry in Australia is thus dependent on the continuing ability to participate, by importing the necessary technology, in the manufacture of new technology products, and to import those products for which local demand is too small to justify any investment in production processes.

ASTEC's views on these considerations can be found in Volume 1 of this report.

FUNDING

27.2.3 Funds for electronics research in the government sector come from the budgets of the particular organisations.

27.2.4 Academic institutions receive their research funding through the Tertiary Education Commission, the Australian Research Grants Committee (ARGC), the Radio Research Board, the Electrical Research Board and, to a minor extent, through grants or contracts from industry. The ARGC grants for 1977 which may be identified as relating to electronics including telecommunications and semiconductor physics, but not including radio astronomy, total \$145,000 or 1.6% of the funds distributed. The Radio Research Board in the year 1976-77 distributed \$150,000 for 60 projects in 16 centres. The Electrical Research Board primarily supports work in power electrical engineering. Of the 40 projects supported in 1977, 6 were substantially concerned with the application of electronics either in the form of instrumentation, signalling or power electronics. Contract research provides only a very small part of the support for R&D in academic institutions.

27.2.5 Funding for electronics R&D in private enterprise comes from internal sources, from specific contracts and from Australian Industrial Research and Development Incentives Board grants. When R&D is undertaken employing internal funds, the expectation is that these will be

directly recovered through increased margins and/or sales. Virtually all R&D undertaken, using internal funds, is directed to product development.

27.2.6 Contract R&D may be reported in two categories. Some companies indicate disenchantment with contract R&D, particularly when carried out for government departments, because this work often does not lead on to the placement of production orders. A number of the smaller companies on the other hand report that they are carrying out contract R&D with apparent success and satisfaction on both sides.

27.2.7 Analysis of the 1975-76 Annual Report of the Australian Industrial R&D Incentives Board indicates that, of the \$19.3million distributed from 1975-76 funds, approximately 60 grants totalling just over \$1million were made to companies in electronics (including telecommunications). Many companies are critical of the rules and procedures relating to industrial R&D grants. Whilst the amount of funds employed is relatively small, it is, however, true that several small companies have benefited. The electronics and telecommunications industry has received about 5% of the funds dispersed to date and without this support, development work would have been at a lower level.

ROLE OF PROFESSIONAL BODIES

27.2.8 At an institutional level electronics R&D in Australia is fostered by bodies such as the Institution of Radio and Electronics Engineers, Australia (IREE), and the Institution of Engineers, Australia. To date they have concentrated their activities on the learned society function, sponsoring conferences and meetings on various aspects of electronics research. They have not sought to stimulate policy development by any direct means.

27.2.9 Each IREE Convention, held every two years, includes approximately 120 papers on R&D in electronics and communications. At the 1977 conference 35% of papers derived from government and semi-government establishments, 15% from industry and 50% from academic institutions.

27.3 DESCRIPTION OF R&D ESTABLISHMENTS

27.3.1 In general terms the organisations which are concerned with electronics R&D within the scope of this chapter, may be classified in the categories:

- Commonwealth government laboratories;

academic institutions; and

industrial companies.

COMMONWEALTH GOVERNMENT

27.3.2 There is no Commonwealth government laboratory which is specifically concerned with R&D in electronics. This contrasts with most major, and many minor, fields of science and technology. For example there is no CSIRO Division of Electronic Engineering, yet there is a Division of Mechanical Engineering. The nearest to the mark would appear to be the Telecom Research Laboratories, whose activities and organisation are covered in Chapter 33 on Telecommunications. R&D in other sectors of electronics is conducted in a number of other government organisations, but always in support of the main activity whether this be defence, atomic energy, radio astronomy or some other activity.

27.3.3 Within these establishments the programs are oriented to the major activity of the organisation although, by the nature of electronics, many of them are of relevance to other areas. Except within the one department, as in Defence, no attempt is made to plan joint, or mutually supporting, programs. Similarly, joint projects with industry or academic institutions are rare.

27.3.4 Some staff within government research organisations are sceptical of the suggestion that there might be benefit in carrying out work with, or in, industry. They do not believe that industrial companies are sufficiently appreciative of, and able to meet, the particularly demanding requirements of the specific areas serviced by government organisations. Further they feel that a greater involvement of industry in research and development for government would not markedly reduce the need for government research establishments and hence would lead to wasteful duplication.

27.3.5 Staff are dedicated to their work, but in a number of establishments, some appear to be frustrated by the parent organisation not making full use of the work carried out. The policies and the nature of operations within government research establishments tend to result in isolation from industry and academic institutions, as well as from the parent organisation and other government establishments. The Commonwealth government establishments are described below.

Defence Science and Technology Organisation (DSTO)

27.3.6 The Defence Research Centre, Salisbury (DRCS) in the DSTO is concerned with work solely for defence purposes. The divisions of DRCS primarily involved with R&D in electronics, are Weapons Systems, Systems Analysis, Communications and Electronic Engineering, and Electronics. Of the 50 professional staff in the Weapons Systems Division, 27 are concerned with electronics directly; there is a total support staff of 35. The Communications and Electronic Engineering Division employ 60

professional and 90 technical support staff. R&D is being carried out in communications (theoretical, not oriented to hardware), electronics including control systems, and underwater communications (the latter being specifically project-oriented). The electronics work includes microelectronics and interactive graphics as well as microprocessor work. The Electronics Division has 140 staff of whom 60% are professional. Its areas of R&D include very low frequency (VLF) communications, an antenna test field, an anechoic chamber in the range 1 GHz to 100 GHz and over-the-horizon radar. Project-oriented R&D is carried out by the radar and electronic tracking group which is concerned with radar assessment and with search and rescue beacons.

27.3.7 Doubts were expressed at DRCS on the viability of bringing Australian industry more closely into defence R&D, but the technical co-operation program which exists between military research and development agencies in the UK, USA, Canada, Australia and New Zealand was praised as being extremely successful in saving redundant work. A recommendation to spend \$80-90million of defence expenditure in industry, made in a recent Parliamentary report [2] was questioned on the basis that such a scheme would not replace the requirement for a body such as DSTO. ASTEC's views on contracting R&D to industry can be found in Chapter 6 of this report.

27.3.8 Within the Materials Research Laboratory (MRL) of the DSTO is a group of four professional and four support staff engaged in R&D on electronics. Their major projects are concerned with providing support for other groups.

27.3.9 The Engineering Development Establishment (EDE) of the DSTO is concerned principally with the definition and realisation of hardware requirements for defence purposes. The bulk of support in applied scientific research is provided by other Defence laboratories. These agencies are concerned with R&D while EDE provides a service for engineering development.

27.3.10 Electronics work within EDE is carried on within the Electrical Engineering Division which has groups concentrating on military telecommunications, electrical power and general electronics, and electrical engineering development facilities. The Power and Electronics Group has six professional staff working mainly in the area of power engineering but with some attention to power electronics. The Military Telecommunications Group has seven professional and two support staff.

27.3.11 The Royal Australian Navy Research Laboratory (RANRL) of the DSTO is organised in five sections, each with electronic engineering support. Of the 83 staff overall there are approximately 6 professional and 10 support staff in electronics. The policy is to buy equipment if at all possible and development is undertaken only when special items are unavailable, too expensive, or when rapid development is essential.

27.3.12 The RANRL does not feel that Australian industry can be successfully involved in their projects because of security problems, difficulties with time scales and product reliability. The contract research

experiences of RANRL with universities are claimed to have been unsuccessful. ASTEC's views on contracting to industry, and technology transfer, can be found in Volume 1 of this report. Work is undertaken in the areas of data handling, microprocessor application, underwater temperature measurement and telemetry, especially at great depths.

Australian Atomic Energy Commission

27.3.13 Electronics R&D within the Australian Atomic Energy Commission (AAEC) is undertaken by eight professional and seven support staff. The R&D programs in electronics consist of instrumentation, and circuit and device design to meet those special needs in nucleonics in which available standard instrumentation is unsatisfactory.

27.3.14 Particular areas of interest to the AAEC are nucleonic instruments, detectors and materials (for nuclear measurements), gas lasers, and photo-electrochemical cells. Some of the circuits developed have been licensed to local companies and to the Atomic Energy Commission of Canada. The AAEC does not manufacture in competition with industry but it seeks to provide the special skills required to fill the strategic gaps in the support available to the nuclear industry. Research on semiconductor materials is directed towards purification, crystal growth and device development for nuclear detectors.

27.3.15 All programs are funded as part of the overall technical program with priorities established at program manager level. The magnitude of the endeavour has decreased by approximately 20% in the past five years. Equipment facilities are good.

CSIRO

27.3.16 The CSIRO Division of Radiophysics concentrated solely on radio astronomy in the period 1955-71, but since 1971 it has undertaken programs of applied radio research. In this area the Interscan microwave landing system has been the major project. In addition a new form of acoustico-optical signal processing is under investigation.

27.3.17 Of the 200 total employees in the Division, approximately 50% provide radio, electronic and computer R&D in support of activities in astronomy and 25% are concerned with applied radio research. The Division has developed good co-operation with Amalgamated Wireless (Australasia) Ltd through the Interscan project.

27.3.18 A number of the Division's activities in support of astronomy involve a high level of expertise in electronic science, notably in antenna, receiver and computer design, but these are directed entirely to radio astronomy applications. The skills could have application outside this field.

27.3.19 Almost every division of CSIRO undertakes some electronics work in support of its primary objectives and activities, and some of this work has resulted in items of commercial value. Divisions which need to make measurements or to collect data have requirements for specialised electronic devices, and these are designed and built by the scientists involved, or

by electronics support staff. Some examples of such electronic devices associated with CSIRO are:

- . wireless hearing aid (National Measurement Laboratory),
- . smoke detector (Division of Chemical Technology),
- . optical fibres (Division of Tribophysics),
- . borehole logger (Division of Mineral Physics),
- . protein analyser (Wheat Research Unit).

Government Aircraft Factories

27.3.20 Within the Government Aircraft Factories (GAF) electronics design and development is well structured, with major subsections comprising an electronics development group and a communications development group. Eleven engineers are employed in the electronics development group, funding coming from general internal capital, recurrent funds, and development contracts from committed customers. As a consequence of some development contract work, GAF have been able to pursue entrepreneurial development projects; they are currently manufacturing telemetry systems which compete successfully in international markets with equipment manufactured by overseas private enterprise.

TERTIARY EDUCATION INSTITUTIONS

27.3.21 All university departments of electrical/electronic engineering and some colleges of advanced education carry out R&D in electronics. In addition several departments of physics within universities carry out research which is related to, or bears upon, the field of electronics. There are 13 universities with electrical/electronic engineering departments. The number of academic staff involved in electronics research and development is approximately 75 (This figure does not include research fellows, graduate assistants, students etc.). Seven colleges conduct some R&D in electronics. Specific details of each university and college department in which electronics R&D development is carried out are not included because the general operation and organisation is similar and well-known in each case. The particular orientation of the various departments is indicated by comments under the different sub-headings of Section 27.4 on R&D programs.

27.3.22 Although academic staff express the wish to work in conjunction with private industry and government organisations, only a few joint projects are in progress. The majority of the collaborative or sponsored projects are with Telecom (see Chapter 33). An examination of R&D programs indicates that academic institutions tend to concentrate their R&D efforts in areas which cannot be readily adopted by Australian industry.

INDUSTRY

27.3.23 Electronics R&D within industry is almost entirely restricted to development aimed at product advantage, there being virtually no basic research. In a high-technology area this deficiency is covered in a variety of ways. Some research information is provided through licensing agreements, some from the parent companies of those with multinational affiliations, and some by regular and frequent overseas visits of technical staff. Furthermore, international research and product information is readily available to support the development of applications for newly available devices.

27.3.24 The range in size, commitment, sophistication and scope of industrial R&D groups is most marked. Because any organisation involved in the electronics industry is dependent on maintaining its technological expertise, some development work is undertaken in almost every company. It is not possible to cover each industrial electronics R&D operation, however, many companies have been contacted during the preparation of this chapter, in order to gain information on a broad cross-section of the industry.

27.3.25 These companies tend to be located predominantly in Victoria although several from NSW and South Australia are also included. It should also be noted that information was summarised from personal and telephone interviews and has not been subsequently verified or authorised by the companies concerned. They serve, collectively, as the basis for, and the illustration of, the general comments made about electronics industry R&D.

27.3.26 Although summary comments may be made which apply quite generally across the government and the academic sectors, R&D in private industry is far from uniform. It is, however, possible to identify various groupings of organisations in which the R&D effort has common features.

27.3.27 One grouping of companies includes those whose business has been concerned with quite large production runs of components or equipment. Sales competition is appreciable, and in many electronic product areas the selling price is dropping or remaining constant, whereas local costs are increasing. There is growing use of automatic assembly techniques and automatic testing. As a result, an increasing proportion of the value of the final product is directly attributable to components. In such a situation R&D is undertaken only where there is confidence that the products resulting from such R&D will be sought in large quantities.

27.3.28 Within Australia, volume markets tend to be concentrated in areas like defence and telecommunications where purchasing is through government contracts. Generally, there has not been a policy to develop collaboration in which companies are encouraged to meet government needs by undertaking R&D which is then followed by volume production. In fact, at present, private industry has very little confidence that R&D which is directed to product development for a particular need will lead to the subsequent placement of government orders for the product with local companies.

27.3.29 The alternative, of seeking to develop products which are capable of capturing a viable export market, also appears to be limited for companies in this first group. Many are affiliated with multinational enterprises and, unless designated as a particular product centre, are prevented by overall company policy from undertaking such development. The remainder lack the financial backing to undertake the commercial risk entailed in entering the export market on the scale required, without the security of a certain local market. Success on the local market is often necessary in obtaining export sales.

27.3.30 The general trend within companies in this category has been to reduce R&D over the years 1973-78 and their expectation is that the reductions will continue in the foreseeable future. These companies typically have competent staff and adequate facilities, but a declining activity and a general uncertainty are manifest in a lack of progress.

27.3.31 Another group of companies includes those whose business is quite small, but who have provided electronic products to a particular segment of the Australian market. Their R&D, which has been almost entirely product development, has been financed from company profits and in a number of cases in part from Industrial Research and Development Incentives Act grants. The decline in the economic situation and competition from imported products have placed financial strains on these companies and they have cut their development programs, usually maintaining some by part-time activity of engineers who also have a design or production role. The altered guidelines for Industrial Research and Development Incentives Act grants have reduced this source of funding for these companies.

27.3.32 A third group of companies includes those based on the application of state-of-the-art technology to very specific areas. They are usually recent in origin and small, but rapidly growing. They operate with low overheads and develop products in which the technological component, as opposed to the hardware and labour content, is high. These companies quite often successfully export their products and are also used at times by larger organisations for contract development projects.

27.3.33 Companies within this group are characterised by high staff morale and a dynamic operation. They combine an interest in, and understanding of, the latest developments in electronic technology with an orientation to application. Such companies are unconcerned about whether the components they use are produced locally or overseas, are less dependent on local market guarantees, but are concerned to improve their means of obtaining information on newly-available components and techniques. Except when they carry out contract development, they do not collaborate with others and tend not to have close ties with educational institutions even though many of the individuals concerned are recent graduates.

27.3.34 The sense of well-being engendered by this group of companies is tempered to an extent by the realisation that only the successful remain. Unlike companies in the earlier groups, anything less than success leads to a rapid demise.

27.3.35 Companies active in R&D are described below. The larger companies, and those whose experience is of interest to the Australian scene, are described in the following paragraphs. Others (not necessarily less important) are listed in Appendix 27.1.

27.3.36 Amalgamated Wireless (Australasia) Ltd (AWA) carries out R&D both within a specific research group, AWA Research Laboratory, and within company product groups. The Research Laboratory has a separate budget of approximately \$600,000 per year which has been declining annually in recent years. A major portion of this budget is derived from external funding sources (e.g. specific research contracts). The only current ARGC grant awarded to industry has been received by the Laboratory for its work on electrets. At present, the group comprises 20 engineers and technicians. The Laboratory's major activities have been in electrets, surface acoustic waves, optical fibres, communications, and aeriels and propagation.

27.3.37 The bulk of development work within AWA is undertaken within the groups of the Engineering Products Division. Each group has its own budget and is responsible for its own development. These groups are:

- . Data Systems Group;
- . Avionic Systems Group;
- . Defence Group;
- . Telephone Switching Group;
- . Test Instruments Group;
- . Microelectronics Group. (This venture, which received establishment support from the government, has been successful and become commercially viable. It has received some government and defence follow-up support. Custom integrated-circuit development is available, and this has found markets in medical electronics, defence and telecommunications); and
- . Traffic Signals Group.

27.3.38 Commonwealth Aircraft Corporation Ltd (CAC). Over the past five years, R&D in electronics within CAC has increased. Prior to this, CAC was involved more in production-line activities in the aircraft industry. In recent times, however, more development work has been done in association with government contracts for modifications and developments mainly allied to the existing aircraft of the armed services.

27.3.39 A significant amount of entrepreneurial development work has also been undertaken, generally in the field of aircraft instrumentation and associated support equipment. Four full-time engineers are committed to development work, and these are supported, where required, by technical staff borrowed from production-line maintenance work. Frequently a development project is jointly undertaken by CAC with other private

companies or sometimes with government departments. This usually follows a successful joint tender.

27.3.40 Consolidated Electronic Industries Pty Ltd, which manufactures professional magnetic-recording equipment and automated broadcast equipment, employs four professional and six support staff in development work undertaken to improve existing products and to provide new ones; a number of these compete successfully in overseas markets. Currently, 40% of local production is exported. R&D has received funding support from Industrial Research and Development Incentives Act grants though not in the past two years. In the absence of further grants, and as current development programs conclude, it is likely that R&D effort will be cut back.

27.3.41 Digital Electronics directs its R&D toward development of product lines for the Australian market. In the past, contract development projects have been undertaken for government agencies but this is now uncommon. Funding for R&D is internally generated and supports three professional and five support staff. R&D is not generally co-ordinated with other bodies. Most development projects are undertaken after a survey of the market reveals an opportunity for a particular digital product.

27.3.42 EMI Electronics, employing 26 engineers, has been exclusively concerned with defence work but is now seeking to diversify, particularly by serving utilities such as electricity generation, water and sewerage authorities. R&D has grown as a result of projects from the government sector, and is important to the company because it sees that it is using a technology with a rapid rate of change and requires R&D to maintain viability. Work has been in the fields of sonar and microprocessor applications in which high reliability is at a premium.

27.3.43 L.M. Ericsson Pty Ltd, a subsidiary of a major international company, is primarily concerned with telecommunications. The comments here relate to its activities in electronics. Research activity, which has slightly increased in the past five years, has been consolidated towards a small number of promising products. The research programs are dictated first by market potential, secondly by the need to support other company activities and finally by the availability of funds. Funds are mostly provided internally with some coming from Industrial Research and Development Incentives Act grants and a small amount from sponsored development. R&D is co-ordinated with the parent company and with several government departments. One joint project has been undertaken with AWA for Telecom. There are 10 professional and 20 support staff, and facilities are satisfactory.

27.3.44 Information Electronics Ltd, which manufactures data handling and display systems, has never undertaken basic research but places importance on the place of development in maintaining company viability. Approximately half the work arises as customer-sponsored programs and half to meet internal needs for product development. The company has received Industrial Research and Development Incentives Act grants in the past, but now, under revised guidelines for such grants, all development funds are internally generated. Eight professional and four support staff

are engaged on development, original product design and product improvement. Development programs are not co-ordinated with other bodies.

27.3.45 Hybrid Electronics Australia Pty Ltd, which is concerned primarily with the development of packaging for custom electronic devices, relies on up-to-date technology to maintain its place in international competition. R&D is therefore important to its operation and directed to the processes which it carries out. Staff is limited to one engineer and one technician with some part-time supplement in the past year. Some funds have been obtained through Industrial Research and Development Incentives Act grants.

27.3.46 IEI Pty Ltd is a world leader in electronic security systems with many patents and an export award for its work. R&D, which is carried on by two professional and three support staff, is important to company operation. Funding is mainly internally generated and programs are directed towards development of new products.

27.3.47 The development work of Philips Industries Holdings Ltd is undertaken by a number of the divisions and subsidiaries as follows:

- Allied Industries Division is concerned with the manufacture of magnet and special wires, plastics and metalware, cables, solar panels and industrial components and systems. Development projects include ignition systems, electronic temperature controls and other devices, and automotive instrumentation. R&D has been decreasing as local products have been replaced by imports. There are 12 professional and 12 support staff. Some development work is carried out for, and funded by, other organisations.

- Elcoma Division. R&D which eight years ago embraced pure research is now restricted to product development, mainly in the field of integrated circuits. Programs are usually determined by customer requirements, and funding obtained from the customer.

- Telecommunications Manufacturing Company. R&D activities which had been in decline owing to company rationalisation and economic circumstances in 1974, are now on the increase. R&D, which is seen as holding a significant place in the overall company, is primarily determined by market forces and the company's international requirements. Funding, which is in the main internally generated, is supplemented by some Industrial Research and Development Incentives Act grants, but no government-sponsored research is carried out. Research effort is co-ordinated within the company, but not otherwise. There are 20 professional and 30 support staff.

- Consumer Products Division. Development work in the Consumer Products Division has been reduced appreciably in recent years because costs are too high for the local development of products which have short production runs. The Division now relies mainly on overseas development through its affiliates. Funding

for any development carried out by the Division, or the Pye and Kreisler subsidiaries, is internally generated and supports about 20 professional and 20 support staff. The company sends some of its engineers to work in Holland on development of products for Australia. Philips are unwilling to spend the time and money (approximately 1-2 years and \$10,000) to train a graduate in their particular specialities without some long-term national planning and stability in the industry. Pye now manufactures only colour TV sets and undertakes its own circuit and chassis development. The company formerly received Industrial Research and Development Incentives Act grants for this work.

27.3.48 Plessey Pacific Pty Ltd. R&D in the Plessey company is centrally located, organised by skill (not by product groups) and serves the three divisions - Telecommunications, Electronic Systems and Components. Staffing of R&D has fallen from 65 professionals in 1972 to 27 now, with 41 support staff, and an annual expenditure of \$1.5-2million. Basic research is minimal except for one person working on ceramics, oriented to transducers. Other areas of current interest are electro-acoustics, surface acoustic wave oscillators, thick film electronics, analogue and digital circuits for radio products, radio communications (voice, data, mobile, rural), microprocessor applications and industrial controls.

27.3.49 Approximately 30% of Plessey research funds are derived from government grants, and the company is active in making proposals which seek such funds. Company expertise in some areas (e.g. ceramic telephone microphone and automatic mail handling) has been lost by the lack of sustaining funds from government sources. With some isolated exceptions it reports few successful joint ventures with government research laboratories, CSIRO or universities.

27.3.50 The policy of Racal Electronics Pty Ltd is determined by its being an independent member of an international group and by the state of electronics in Australia in recent years. Development is aimed at international markets and not at local requirements, because many local specifications are not compatible with world standards. Also, development contracts do not guarantee sales. Company expertise is in military electronics, radio receivers, digital communications and associated equipment. Thirteen engineers are employed in development associated with products. Little work of a fundamental nature is performed, reliance here being placed on university and overseas groups. A need for the company to extend its liaison with academic groups is recognised.

27.3.51 Siemens Industries Ltd maintains a limited R&D effort in Australia within a design group of five engineers. R&D programs emphasise development although the company has done, and will do, basic research and development provided costs can be recovered. Funding is derived from a combination of internal funds, design contracts and, formerly, Industrial Research and Development Incentives Act grants. There is co-ordination with other companies, commonly the users of the products under development. Siemens have placed study contracts with university staff.

27.3.52 Standard Telephones and Cables Pty Ltd (STC). Company activities within STC are almost entirely communications-based, development being based on overseas research, and on access to information from ITT, the parent company. Fifty-two professionals are currently involved in development in the various product-oriented groups, compared with 95 in 1972. The current budget is \$2.8million. The product groups are Electronic Switching (by far the largest), Electronic PABX, Handsets (Digital dialling), Transmission Equipment, and others including thick-film, power-line filters. Company policy directs its R&D to products it wishes to supply. R&D is primarily internally funded. No development contracts have been obtained in the past year although there had been some small grants previously.

27.3.53 Teletronics Pty Ltd is active in the field of implanted cardiac pacemakers and bone growth stimulators. The company success, which has been substantial (400 employees in Australia, manufacturing plants in France and USA and a growth rate which has doubled the company size each year), is based on the use of advanced technology ahead of overseas companies. Development work is, therefore, highly significant in company operations and is currently staffed by six professional and six support staff. Work is carried out on electronic circuit design, system specification, packaging, fabrication, and materials compatibility and reliability. Some work on integrated circuit fabrication has been carried out for the company by AWA and some development work has been sub-contracted to universities. No external R&D funds are received. Development programs are determined by marketing decisions, customer requests and suggestions.

27.3.54 Varian Techtron Pty Ltd. This company manufactures atomic absorption spectrometers, a CSIRO invention. R&D, which is directed to developing new designs for production and improved methods and techniques, has remained static over the past five years in terms of total expenditure, and declined in terms of staff numbers. There are 12 qualified electronic engineers on the staff. Funding for R&D is provided by sales revenue and minor government support.

27.4 DESCRIPTION OF R&D PROGRAMS

27.4.1 The information contained in this section is not as detailed nor as comprehensive as desired. Whilst most universities and colleges readily provided information of their programs, government laboratories and industrial companies, understandably, were more reticent, usually preferring to indicate only the general areas of their current interest.

27.4.2 A picture emerges of R&D in which the academic institutions tend to be concentrating on fields in which a substantial body of knowledge may be built up. Examples of such areas which are currently receiving considerable attention are microelectronic materials and devices, digital systems, microwave materials, microwave devices and systems. On the

other hand industrial companies are concerned almost exclusively with product development and hence emphasise such topics as transducers, instrumentation and microprocessor applications.

27.4.3 Of all the work reviewed the only major project in which a degree of co-ordination and involvement of government, private industry and educational institutions had been achieved was the work on optical fibres. Major R&D programs are described below.

MICROELECTRONIC MATERIALS AND DEVICES

27.4.4 The Microelectronics Group of AWA represents almost the only industrial activity in this area. It has established a major facility for development of custom integrated circuits. Within the Research Division at Plessey some thick-film work is being undertaken, mainly in conjunction with development of an active ceramic microphone.

27.4.5 The Department of Solid-State Electronics within the University of NSW is working on development of diffusion-based equipment for integrated circuit processing. Devices produced recently have included field effect transistors and bipolar devices. Studies of transistor and charge-coupled devices are in progress. Work is in hand on various forms of metal-insulator-silicon photovoltaic cells for solar energy conversion.

27.4.6 In the Electrical and Electronic Engineering Department at the University of Western Australia, work on silicon technology and devices is currently concerned with the development of the technology of planar silicon devices, and with the production of specialised field effect transistors and capacitors. In particular the effect of fast-diffusing, metallic impurities on semiconductor interfaces is being investigated. The development of charge coupled devices is also in progress with particular interest in imaging applications of these devices.

27.4.7 At the Department of Electrical Engineering within the Royal Military College, work is in progress to investigate the electrical and optical properties of electronic materials deposited in thin layers. A study is also being made of the fabrication of thin film devices for use in the construction of flat panel displays.

27.4.8 Several Physics Departments at various universities are undertaking fundamental studies associated with semiconductor materials without any being identified as directly related to electronic engineering.

27.4.9 There is a limited (i.e. thin and thick film) microelectronics facility at the Defence Research Centre, Salisbury (DRCS) for the study and development of defence oriented microcircuits and techniques. Considerable effort has been expended in computer-aided design including interactive computer graphics and a computerised artwork-generating system. Both thick and thin film devices are produced by using vacuum and ion beam techniques. Activities range from research to the manufacture of prototype microcircuits.

27.4.10 The University of Adelaide is conducting research in computer-aided design for the development of large-scale integrated microcircuits as an end product. The work is proceeding in co-operation with the integrated circuit laboratories at the Universities of NSW and Edinburgh. Expertise in the manufacture and modelling of integrated circuits is being developed.

27.4.11 The Department of Communication and Electronic Engineering at the Royal Melbourne Institute of Technology (RMIT) has a research program centred on the application of ion implantation in both silicon and gallium arsenide to electronic device fabrication. Co-operative work has been undertaken with many Australian research and development groups and with two US companies. Development is also proceeding in ion implanter technology. An interactive computer graphics system is being developed for layout of printed circuit, thick film and microelectronic masks.

MICROWAVE MATERIALS AND DEVICES

27.4.12 Within the Department of Electrical Engineering at the University of Queensland, there are investigations of the fundamental properties of semiconductors used in microwave devices, together with the development of solid-state oscillators and microstrip circuitry. Particular projects include noise in specialised diodes and oscillators; microwave integrated circuits; thick-film microwave hybrid circuits; microwave resistive mixers; microwave parametric circuit design; and high-frequency solid-state sources.

27.4.13 At the Department of Electrical Engineering of the University of Adelaide, work on microwave devices has been focussed on the Gunn device and includes material preparation, device construction, microwave mount design and computer simulation studies. Devices used in the experimental investigations are made of gallium arsenide. In addition the design of microwave mounting structures for oscillator devices is being studied, with particular attention focussed on high efficiency, continuous wave, oscillator devices.

27.4.14 The Department of Electrical Engineering at the University of Newcastle is investigating the modelling and use of Gunn effect devices in various modes and circuits. At the University of NSW, the Department of Solid-State Electronics has in progress a study of electron transport in microwave field-effect transistors.

27.4.15 The School of Electronic Engineering at the South Australian Institute of Technology has a project to investigate the feasibility and limitations of the thick-film process for microwave signal processing devices, to develop and characterise manufacturing techniques and to make process and design data available. The School also conducts research in materials, concerned mainly with material properties at microwave frequencies, particularly those of dielectrics and semiconductors. RMIT has been investigating design and fabrication techniques for linear, passive

and active networks at microwave frequencies, together with design techniques for low noise amplifiers.

27.4.16 Within the Electronics Research Laboratory of DRCS there exists considerable expertise in research, development, design and construction of prototype microwave components. These components range from printed circuit antennae, through waveguides, couplers and modulators to detectors. The emphasis is on military radar systems, however, a general capability over the complete microwave technology spectrum is maintained.

OPTICAL DEVICES

27.4.17 AWA Research Laboratory began research and development on optical fibre communications in 1972 and is continuing work in conjunction with the Department of Defence and Telecom. Low-loss optical fibres are being produced experimentally. Experimental optical-fibre cables are being manufactured with the co-operation of Olex Cables Ltd.

27.4.18 The Department of Communications at the University of NSW has a number of research programs concerned with the study of a range of optical fibres for wide-band systems, and the effects of manufacturing tolerances on signal distortion. There is also a project concerned with optical second harmonic generation in liquid systems.

27.4.19 The Department of Electrical Engineering at the University of Queensland has comprehensive facilities for research into miniaturised lasers and integrated optical guiding structures. Current projects include electron beam techniques for integrated optics, lasers, thin-film waveguides, polycrystalline semiconductors for integrated optics, and active devices for integrated optics. There is also a project concerned with semiconductor optical modulators in the infrared region.

27.4.20 The Department of Electrical and Electronic Engineering at the University of Western Australia is working on the development of planar, optical waveguides and has produced structures providing both optical coupling and processing on a planar substrate. The work, which is being carried out in co-operation with the Telecom Research Laboratories, is concerned with developing integrated optical circuits. The Department of Communication and Electronic Engineering at RMIT is studying the properties of ion implanted waveguides for integrated optic structures.

27.4.21 Expertise in basic optical technology is maintained at both Materials Research Laboratory (MRL) and DRCS. At DRCS a basic research program is carried out into understanding the growth processes and bulk properties of single crystals for electro-optic applications. In addition, studies of particle beams for the deposition, shaping or modification of the physical properties of electro-optic materials, and of the physics of thin films, are being conducted. These techniques will be applied in devices such as lenses, guides, amplifiers, couplers and modulators fabricated on the micro scale. Studies are being conducted at both Engineering Development Establishment (EDE) and DRCS into the application of fibre optics and integrated optics for defence communications.

SURFACE ACOUSTIC WAVE (SAW) DEVICES AND SYSTEMS

27.4.22 Plessey Research Laboratory has a program of research in SAW oscillators. The AWA Research Laboratory has been working on the physics of SAW propagation and SAW oscillators; computer design techniques have been developed and a complete SAW oscillator-modulator system has been developed for military application. AWA now offers an integrated design and fabrication service for small quantities of custom SAW devices.

27.4.23 At the University of NSW there are research programs concerned with electronic devices based on the non-linear interaction of surface elastic waves, and with the potential for application of SAW in high speed thermal detectors and in image forming devices. The Department of Electrical and Electronic Engineering at the University of Western Australia is working on the modulation of laser light by interaction with bulk and surface acoustic waves propagating in solids. Work is now in progress to use sound waves up to microwave frequencies in these modulators.

27.4.24 The Department of Communication Engineering at La Trobe University is developing microwave oscillators using SAW resonators. The Advanced Engineering Laboratory of DRCS carries out research into SAW devices, and it designs and produces surface acoustic wave devices for radar and secure communications applications.

COMPUTING DEVICES

27.4.25 At the Royal Military College there is an investigation of methods of overcoming the limitations on the maximum addressable memory in minicomputers by means of restructured architecture. Computing hardware research at the University of Adelaide is concerned with virtual storage concepts in minicomputers, and with fast arithmetic processes for digital computers. At the Department of Computer Science, University of NSW hardware projects include computer systems in which machine functions may be interchangeably realised as hardware, microcode or software, real time computing systems; and the measurement and observation of the activity of computer hardware systems in operational situations.

27.4.26 All laboratories of the Defence Science and Technology Organisation (DSTO) are heavily dependent on digital computers (large scale, mini and micro) and those concerned with weapons analysis (DRCS, ARL) operate hybrid systems. DRCS in particular also develops customer computer hardware such as analogue-to-digital converters and processing equipment for digital and analogue signals.

TRANSDUCERS

27.4.27 Electrets, which may be used in microphones and loudspeakers, or as sensing elements in pressure and temperature sensors, have been the subject of research in the AWA Research Laboratory. Major

achievements of the project have been the development of an electret-based replacement for the carbon telephone microphone; the development of a new, and very simple, electric charging technique with liquid contacts at high voltage; the study of electrets for transducers in underwater sound applications; and the development of a new technique for measuring the spatial distribution of charge and polarisation through the electret.

27.4.28 The Plessey Research Laboratory has undertaken research on ceramics, oriented to transducer development. Electro-acoustics within water and air are also studied. The research is in support of hydrophone manufacture and has also led to the development of an active ceramic microphone.

27.4.29 The Dynavac Company has developed electronic vacuum gauges in support of their major product interest - vacuum systems. Digital Electronics has developed a wool-thickness measuring system. Bayliss Electronic Industries Pty Ltd have developed new methods for metal and weapon detection in support of their major product line. Integral Design is developing an earthquake detector for use in construction projects for the damming of rivers.

27.4.30 The RAN Research Laboratory (RANRL) is undertaking development work on temperature measurement in water. RANRL and DRCS both undertake research into undersea detection including the design of appropriate transducers. RANRL also provides a service for hydrophone calibration. The Aeronautical Research Laboratories (ARL) have expertise in mechanical and electrical transducer development associated with aeronautical studies. The Electronics Research Laboratory of DRCS develops seismic, acoustic, magnetic and optical sensors for defence surveillance purposes.

DISPLAYS

27.4.31 The development group within the Siemens company has produced a display device which is to be used in systems such as computerised, race-result displays. Information Electronics has a major development program directed to the production of equipment for input, transmission, decoding, display, etc. of Chinese characters. This program has reached the pre-production, prototype stage.

27.4.32 The Department of Electrical Engineering at the University of Newcastle is developing a compact, visual-display unit for both monochrome and colour. The University of Adelaide is engaged on the development of both monochrome and colour high-resolution display systems using semiconductor stores, for use as computer terminals.

27.4.33 Commercial, and custom-built, cathode-ray tube displays are adapted by DSTO generally to such applications as sonar, night vision, infrared imaging, and radar. Some research is conducted into the

man/machine interface as typified by displays, and into pattern recognition and interpretation.

CRYSTALS

27.4.34 Hy-Q Electronics have conducted research into quartz crystals and their applications, but are now tending to turn their attention away from new products towards new manufacturing processes.

ELECTRONIC APPLICATIONS

Signal processing

27.4.35 Various methods of implementing digital filters using both serial and parallel logic elements are being investigated at the University of Newcastle. Limit cycle oscillation in digital filters, and logical and random operations in signal processors are topics of research at the University of Adelaide. Signal processing research at the University of Queensland is concerned with target recognition by radar, satellite system design for navigation and communication, and speech recognition studies. At the University of NSW studies in this area are concerned with the development of new types of non-linear filters. Several of these are being studied for the reduction of noise in audio systems.

27.4.36 The Physics Department of the James Cook University of North Queensland has a research program on applications of phase-locked, loop circuits to VHF satellite signals and to VLF beacons. In the Electrical Engineering Department, work is continuing on analog-to-binary conversion, and on the development of very high quality stereo FM exciters and voltage-controlled oscillators. There is also a project which is directed to the investigation of oscillations in phase-locked loops with wide-loop, filter bandwidths. Active filter design is another area of interest.

27.4.37 The Department of Communication and Electronic Engineering at RMIT has developed a frequency band translator, for any desired portion of the speech spectrum, to assist in speech therapy. Research is currently proceeding in speech analysis and synthesis. Equipment to produce real-time histograms of the period between successive peaks in time-varying analog data has recently been developed for the Queen Victoria Hospital, where it is used for the analysis of breathing patterns.

27.4.38 The only commercial, signal-processing equipment which was reported as 'under development' was a program-limiting amplifier, by Design Two Thousand, which is required for a dispatch conference line they are producing for an airline company.

27.4.39 Extensive R&D on signal processing hardware and software techniques is performed at DRCS. The research is in support of radar,

optical and underwater surveillance and of defence communications projects. DRCS has the capability to develop and to construct signal processing hardware for dedicated applications.

Instrumentation and control

27.4.40 IEI Pty Ltd are developing heat and movement detectors as part of their program of R&D in the field of security products and systems. Astronetics are working on the development of a modified hot water thermostat for a power authority. Digital Electronics are working on noise-monitoring equipment. Integral Design are developing a computer-based, mobile-vehicle monitor for a brake manufacturer. This system will monitor acceleration, retardation, temperature, pedal movement etc. Honeywell have developed a small, communications-type, security controller. Design Two Thousand have development programs for solid-state control of a refrigeration system and a solid-state taximeter. Belco are developing a proximity switch and emergency warning systems for high rise buildings.

27.4.41 The Commonwealth Aircraft Corporation, as a spin-off from electronic support development for the Mirage, has recently developed a digital, engine-speed detector and indicator. Scientific Electronics have a development program in frequency counters and Belco have solid state counters and electronic digital counters under development. The Royal Military College is investigating the use of commercially available integrated circuits and other components as possible bases for inexpensive digital measurement of such quantities as power and power factor.

27.4.42 At La Trobe University several projects have been undertaken in the field of vehicle detection and control. These include the improvement of vehicle detecting loops for the Australian Road Research Board and a new method of interlocking traffic signals, without communication links, for the NSW Department of Main Roads. AWA are developing microprocessor-based traffic controllers, and have also performed research into vehicle detectors, and into the reliability of traffic signals.

27.4.43 Deakin University has two projects involving microwave power applications in agriculture. The first involves the development of a device which would focus pulsed, microwave power for the purpose of controlling insect infestation in agricultural products such as wheat. The second aims to design and to construct a seed germinator with appropriate exposure time for seeds which are difficult to germinate.

27.4.44 All laboratories of DSTO have devised instrumentation systems for various purposes using combinations of commercial and custom-built components. Typical are:

- . MRL: studies of explosives and ammunition;
- . ARL: aerodynamic (wind tunnel and free flight), structural and aircraft engine investigations;

- . DRCS: complex systems using radar, telemetry and optical equipment for measuring the in-flight performance of aircraft and missiles at Woomera;
- . RANRL: shipboard, data-acquisition systems for naval exercise analysis.

Microprocessor applications

27.4.45 All DSTO laboratories make extensive use of microprocessor chips. In particular MRL has set up a small section, with the necessary diagnostic equipment, to advise on application of microprocessors, and to program such systems for laboratory users.

27.4.46 The following list shows a number of private industrial companies and some of the areas in which they have developed work centred on the application of microprocessors:

- . Astronetics - alarm monitoring at power stations
 - programmed switching of supermarket lights
- . Sepac Industries - speech scramblers
- . Australian Controls - washing machine and oven timers
- . Commonwealth Aircraft Corporation - cable loom checking
- . IEI Pty Ltd - security systems
- . Nilsen Development Laboratory - industrial control and protection systems
- . Electronic Control Systems - display systems
- . N. Heather - industrial controls
 - temperature control of laboratory presses
- . Plessey - mobile radio data link
 - industrial controls
 - timber-grading machine
- . Varian Techtron - atomic absorption spectrometers
- . AWA - traffic signal control

27.4.47 Amongst the university departments of electrical and/or electronic engineering the following microprocessor activities have been identified:

- . Newcastle
 - remote shape-measurement with possible application to log grading in saw mills
 - mine conveyor supervision and control
 - sawmill bench control
 - visual display unit
 - adaptive equaliser for digital data links
- . Wollongong
 - interfacing and control of mass spectrometers
- . Adelaide
 - implementation of fast Fourier transformation
 - high speed emulation of a PDP8 control processing unit
- . Queensland
 - synthesis of speech
- . NSW
 - PDP II emulation
 - the implementation of large commercial systems on microprocessor-based computers
 - adaptive receivers for digital communication systems
- . WA
 - power systems control
 - signal processing
- . James Cook
 - data acquisition system for recording braking forces and acceleration of moving vehicles
- . Deakin
 - multiple-choice machine for School of Education
 - interactive data logger

27.6.48 Within the Institutes of Technology the following microprocessor activities have been reported:

- NSW
 - adaptive control in a power station
 - data storage on a cassette deck
 - Footscray
 - numerical control of machine tools
 - hierarchical control of large industrial systems, in particular a power station coal conveyor system
 - power system protection
 - testing of power system protection
 - automatic plethysmograph
 - Royal Melbourne
 - airborne data acquisition system
 - network analyser
 - incorporation of calculator functions
 - lung capacity measurement
 - data communication

Data acquisition and telemetry systems

27.4.49 L.M. Ericsson have under development for the Bureau of Meteorology a data collection system which polls remote points for information to be sent to the main collection centre. Schick Electronics are developing telemetry equipment for use by utilities and Digital Electronics are developing electronic data-logging equipment as a new product line for the company.

27.4.50 The School of Physics at the University of Sydney has a Telemetry Group that is active in research in this field. Current projects include long-range tracking systems for animals (a similar project is current at the University of Adelaide), transponding systems, biotelemetry (implantable systems) and a study of optimum systems. At the University of Western Australia a telemetry system for monitoring the dynamics of long trains has been under development. A serial computer interface for translation of cassette tapes containing event and analogue data is also under development at the James Cook University of North Queensland. The Royal Melbourne Institute of Technology (RMIT) has developed a computer-compatible, student response and assessment recorder which collects and processes digital data serially for communication between students and lecturer.

27.4.51 The Royal Australian Navy Research Laboratory (RANRL) is working on systems for data handling, data logging, automated measurement and telemetry. Particular fields of interest are underwater telemetry and deep water telemetry for ocean monitoring. The use of

telemetry in Australia for weapons and rocket tests was pioneered by the Defence Research Centre, Salisbury (DRCS) which has designed, developed and modified telemetry systems for many uses, including aircraft and missile performance.

Electronic test equipment

27.4.52 L.M. Ericsson are developing minicomputer controlled equipment for testing of printed circuit boards in their own and other manufacturers' plants. Collins Radio are developing specialised test equipment. DSTO laboratories have extensive holdings of electronic test equipment, and maintain appropriate sub-standards for its calibration.

Power electronics

27.4.53 L.M. Ericsson are working on the development of power supplies, power instrumentation, rectifier systems and power systems. Schick Electronics have development projects in hand on inverters, lighting and motor controls. Westinghouse Brake and Signal are maintaining a small amount of development in industrial control electronics and rectifiers. Sepac Industries are working on power converters for reverse polarity vehicles. Scientific Electronics are undertaking development of power supplies, power inverters and converters and switchmode power supplies. Nilsen Development Laboratory is developing electronic protective relays.

27.4.54 The University of Newcastle has a development project on a range of solid-state protection relays. At the Royal Military College, control by digital switching of both rotating and linear machines is under investigation.

27.4.55 The University of Adelaide has a research program on variable-speed drives, investigating novel control methods for control of both direct current and induction motors with particular application to electric vehicles. The University of Western Australia is investigating induction motor control, and control of battery-powered electric vehicles. At RMIT the Power Electrical Engineering Department has been investigating the application of power electronics to electrical machines and power systems, while the Communication and Electronic Engineering Department has been developing remote meter reading systems. Also a miniature, high-voltage, direct current converter has been developed for an Australian company.

Optical systems and applications

27.4.56 The Royal Military College has studies directed towards the application of optical holography for non-destructive testing and the formation of coloured images of both stationary and vibrating objects. The Physics Department at the James Cook University of North Queensland has a current program of research into various forms of circuits for light detection. At RMIT an optical scanning system, with electronic signal processing, has been applied to the automatic measurement of plant roots for the Department of Agriculture.

27.4.57 Stemming mainly from its support for Woomera, DRCS has considerable expertise in conventional and electro-optics. A current project in this field is a laser bathymeter for hydrographic survey of coastal waters. Other work concerns the technology of multi-layer coatings to improve the transmission efficiency of optical systems, and the detection and classification of infrared emissions from military targets. MRL conducts research into the basic physics of high-energy gas lasers, and associated propagation effects. This establishment also works in the field of countermeasures to optical surveillance, i.e. camouflage.

NOTES AND REFERENCES

1. Industries Assistance Commission, 'Telecommunications Equipment'. Australian Government Publishing Service, Canberra, 1976.
2. Parliamentary Joint Committee on Foreign Affairs and Defence, 'Industrial Support for Defence Needs and Allied Matters', Parliament of Australia, Canberra, 1977.

APPENDIX 27.1

ELECTRONICS R&D IN SOME AUSTRALIAN COMPANIES

<u>Company</u>	<u>Area of R&D/ Type of Activity</u>	<u>Resources for R&D</u>	<u>Finance Sources</u>
A. and R. Sonar Electronics Group	Consumer product development	part-time activity of staff	Formerly AIRDIB grant - now ceased
Andrew Antennas	Product development of antennas (incl. UHF and microwave), wave guides and cables, for customer needs	20% of (unspecified) company effort	-
Antenna Engineering Australia Pty Ltd	Antennas and aerials, wave guides, and aerial feed equipment	4 professional, 1 support	Internal
Armstrong Audio-Video Pty Ltd	R&D on audio and videotapes to develop new equipment and techniques	1 professional, up to 5 on occasions	-
Astronetics Pty Ltd	Telemetry and remote control custom development	2 professional, 4 support	Mainly from charging to projects. Some AIRDIB
Austenna Pty Ltd	Antenna development for UHF television	1½ professional	Mainly internal. Some AIRDIB

Australian Controls (Division of Actrol Industries P/L)	Adaptation of overseas innovations in control of domestic appliances	1 professional, 1 support	-
Bellco Pty Ltd	New product development in switches, timers and counters, etc.	1 professional 3 support (25% of time)	Internal
Brodribb Pty Ltd	Transformers and power supplies	2 professional, 2 support	Internal
Collins Radio Co. (Australasia) Pty Ltd	Design and construction of VHF radio transmitters and receivers	2 professional, 2 support	Internal; Government contracts
Design Two Thousand Pty Ltd	Custom design for customer requests	2 professional, 1 support	Customer contracts, some AIRDIB
Dynavac Pty Ltd	Vacuum systems	1 professional (50% time)	-
Electronic Control Systems	Design and manufacture of video terminals and micro- computer displays; product development and software	4 professional	Mainly internal, some AIRDIB
Fairey, Australasia Pty Ltd	Defence equipment	4 professional (part-time)	DRCS contracts, internal, some AIRDIB
Noel M. Heather & Co Pty Ltd	Microprocessor-based system for industrial control	20% of (unspecified) expenditure	Internal
Hy-Q Electronics Pty Ltd	See 27.4.34	4 professional, 8 support	Internal (formerly some AIRDIB)

Integral Design Pty Ltd	Equipment development for customers	3 professional, 3 support	Internal
Nilsen Development Laboratories Pty Ltd	Product development of industrial controls and switchgear.	2½ professional, 5 support	Internal (formerly some AIRDIB)
Rifa Pty Ltd	Development of electronic components; some fundamental research on dielectrics	-	-
Scientific Electronics Pty Ltd	Product R&D in electronic power supplies	\$20,000 p.a.	Internal
Sepac Industries (Australia) Pty Ltd	Development and custom design of communications peripherals	3 professionals	Internal, AIRDIB
Schick Electronics Australia Pty Ltd	Efficiency and cost improvements on electronics and lighting devices	2 professional, 2 support	Internal, some defence contracts
Sentron Instruments	Contract R&D in broadcast, recording and automatic operation.	2 professional	Contracts
Thycon Systems Pty Ltd	R&D in power electronics and control	2 professional, 2 support	Internal, some AIRDIB
Westinghouse Brake and Signal Co (Aust) Pty Ltd	Solid-state devices, data communication systems.	1 professional, 2 support	-

CHAPTER 28
FOOD

Photograph: Identification of volatile flavouring constituents of foods by the application of gas chromatography and mass spectrometry, at the CSIRO Food Research Laboratory, North Ryde, NSW.
(Photograph courtesy CSIRO Division of Food Research).

CHAPTER 28

FOOD

28.1. INTRODUCTION

28.1.1 Foods are the plant and animal products of land and sea that man eats and drinks. Food research and development is conventionally but somewhat arbitrarily divided into the two areas - food science and food technology. Food science is concerned with the composition, structure and properties of foods, including sensory qualities and nutritive value, and with the mechanisms and agencies that cause spoilage and deterioration. It necessarily embraces a number of disciplines, e.g. chemistry, physics, biochemistry, microbiology, plant and animal physiology, and applied psychology. Food technology is concerned with all the technical stages from harvest to consumption in systems for the conservation, distribution and marketing of foods, i.e. with techniques of preservation, processing, packaging, storage, and transport of foods, and with wholesomeness, acceptability, and safety to the consumer.

28.1.2 Food R&D has interfaces with several other areas of applied science, e.g. agriculture, fisheries, engineering, and the public health areas of microbiology, toxicology and human nutrition. Clear boundaries can seldom be drawn with these adjoining areas and there is bound to be some overlapping coverage.

28.1.3 In general, however, this chapter does not cover the production or biology of food plants and animals. One exception is the production of food from microbial sources which does fall within food R&D. Other areas also included in food R&D are fermented beverages, the utilisation of wastes and the control of pollution. Extension activities concerned with the dissemination of the findings of food R&D are also involved. There will be some coverage of public health aspects, such as food-spoilage microorganisms of public health significance and food additives and contaminants with toxicological implications. However, Human Nutrition as a general area will be covered in Chapter 40 ('Health').

28.2 POLICIES AND AGREEMENTS

COMMONWEALTH-STATE CO-OPERATION

28.2.1 Under the Standing Committee on Agriculture, the Commonwealth Horticulture Committee has two sub-committees relevant to food R&D. The Fruit and Vegetable Post-harvest Research Sub-Committee is made up of representatives of State Departments of Agriculture, the Commonwealth Department of Primary Industry, the CSIRO Division of Food Research, the

CSIRO Division of Horticultural Research, and the New Zealand Department of Scientific and Industrial Research. The representation of New Zealand is unusual but may be attributed to a long history of co-operation in post-harvest research between the two countries.

28.2.2 The Fresh Fruit Disinfestation Sub-Committee consists of representatives of the State Departments of Agriculture, the Commonwealth Department of Primary Industry, and the CSIRO Division of Food Research. This sub-committee is concerned with treatment of fruit for disinfestation from insect pests, and it is responsible for the allocation of research funds for this purpose. The funds are derived from contributions by Commonwealth and States according to a formula (Table 28.1). Also shown in Table 28.1 is the allocation of funds to the research groups in State Departments of Agriculture.

TABLE 28.1
FRESH FRUIT DISINFESTATION COMMITTEE

<u>Source of Funds</u>			<u>Allocation of Funds</u>	
	<u>%</u>	<u>1977-78</u>		<u>1977-78</u>
Cwlth	50	\$ 64,323	Qld	\$ 26,600
NSW	12	15,437	NSW and CSIRO(a)	
QLD	10	12,864	Salaries (1 profes-	52,845
WA	6	7,719	ional, 3 support staff)	
Vic	12	15,437	Other	<u>21,200</u>
SA	6	7,719	WA (2 support staff)	74,045
Tas	4	<u>5,146</u>	Tas	22,000
Totals		<u>\$128,645</u>		<u>6,000</u>
(1976-77		\$106,008)		<u>\$128,645</u>

(a) This entry refers to the disinfestation research program at the Gosford Horticultural Post-harvest Laboratory. This Laboratory is a joint venture of CSIRO and the NSW Department of Agriculture.

28.2.3 Three sections of the food industry in Australia, the bread, sugar, and wine industries, have formed associations for the purpose of supporting R&D.

28.2.4 The Bread Research Institute (BRI) was founded in 1947 by the bread industry, and in 1951 it was constituted as an industry research association with the support of CSIRO. Today the Institute is supported also by the flour-milling and wheat industries. It is governed by a Council comprising representatives of the bread industry, a representative of the Flour Millers' Council of Australia, a representative of the Australian Wheat Board and representatives of the CSIRO.

28.2.5 The Sugar Research Institute (SRI) was founded in 1949 by 26 Queensland sugar mills and is controlled by Sugar Research Ltd which is a

company limited by guarantee. All the sugar mills (30) in Queensland are now members of Sugar Research Ltd. Until 1967 Sugar Research Ltd was wholly supported by annual levies on the member mills but since that time CSIRO has made an annual grant of \$1 for each \$2 contributed by industry up to the present limit of \$400,000. The annual research budget is approximately \$1.75million.

28.2.6 The Australian Wine Research Institute (AWRI), a company limited by guarantee, was established in 1955 when the Wine Export Bounty Act was repealed and the sum of \$1 million remaining in the Wine Industry Assistance Account was credited to a Wine Research Trust Fund. Of this sum \$200,000 was available for capital expenditure and \$0.8million was held in the Trust Fund. Interest from the Trust Fund (\$54,400 in 1976-77) supplemented by monies from the Commonwealth Department of Primary Industry, CSIRO, the Australian Research Grants Committee, and the Australian Wine Board (the source of whose funds is a levy on the Australian wine industry under the Wine Grapes Charges Act, 1929) provides a total income of \$355,000. AWRI is controlled by a board of directors representing the wine industry, the Commonwealth Department of Primary Industry, CSIRO, and the University of Adelaide.

28.2.7 Whey Products Australia Ltd is a company formed in 1972 by nine Australian dairy companies to support research on whey utilisation, and, specifically, a collaborative program between the CSIRO Dairy Research Laboratory and the Victorian Department of Agriculture.

28.2.8 Under industry associations, the Council of Australian Food Technology Associations (CAFTA) should also be mentioned. CAFTA (founded 1949) which, through its member Associations in the six States, brings together 443 companies in the food and ancillary industries, and which has links with 20 kindred associations, is not specifically concerned with R&D but with technical matters relating to Australian and international food standards and regulations. CAFTA provides representation for the food industry on the Food Standards Committee, and the Food Science and Technology and Food Microbiology Sub-committees of the National Health and Medical Research Council. It also publishes 'Food Technology in Australia' which it shares as an official organ with the Australian Institute of Food Science and Technology.

28.2.9 Another industry association is the Western Australian Association for the Promotion of Education and Research in the Dairy Industry Inc. (founded 1966) which has 52 members.

INTERNATIONAL COMMITMENTS

Association of South East Asian Nations

28.2.10 Through the Australian Development Assistance Bureau (ADAB) of the Department of Foreign Affairs, Australia made available to the ASEAN countries (Singapore, Malaysia, Thailand, Philippines, and Indonesia) \$5million in 1976-77 for the support of R&D and training programmes concerned with food. This sum was increased by \$10million in August 1977. The allocation of this money is in the hands of the ASEAN

Standing Committee which has recognized two projects: the Protein Project and the Food Handling Project. The Protein Project, allocated \$2.5million, is sponsoring food R&D at 26 institutes in three major areas: low-cost protein-rich foods for children and other vulnerable groups, the processing and use of full-fat soy flour, and fermented foods from soy and other protein sources. The Food Handling Project, allocated \$1.8million, is concerned with post-harvest losses of foods, particularly rice, fruit, vegetables, meat and fish. A Post-harvest Training and Research Centre was completed at the University of the Philippines, Los Banos in September 1977.

Codex Alimentarius Commission

28.2.11 Australia is a member of this joint commission of FAO and WHO which has the task of writing international standards for the composition, quality, and safety of foods. It is a body which uses the results of food R&D but does not itself carry out or support food R&D. The Commonwealth Department of Primary Industry provides the Australian contact with the Codex Alimentarius Commission.

International Union of Food Science and Technology

28.2.12 Australia is a member of IUFOST, the representative body being the Australian Institute of Food Science and Technology. IUFOST does not support food R&D but encourages exchange of information on food R&D through committees, working parties, symposia, and congresses.

Other international involvement

28.2.13 Australia is a member country of the International Institute of Refrigeration. The formal arrangements are handled by the Department of Foreign Affairs. Australian activities are organised by an Australian National Committee, and Australia is represented on the Institute's scientific and technical Commissions. Australia is also a member of the International Union of Pure and Applied Chemistry (IUPAC) through the Australian Academy of Science. IUPAC touches the area of food R&D through, for instance, its Commission on Food Contaminants and the Commission on Oils and Fats, on each of which Australia is represented by staff from CSIRO Division of Food Research. In addition, Australia is represented on the International Commission on Microbiological Specifications for Foods, an independent commission of individual experts which grew out of the International Association of Microbiological Societies. Australia is also a member of the International Dairy Federation through the Australian National Dairy Committee (and is active in several technical committees) and of the International Union of Nutritional Sciences (through the Australian Academy of Science).

28.3 ORGANISATION OF R&D

COMMONWEALTH GOVERNMENT

CSIRO

28.3.1 The major effort in food R&D in Australia is made by CSIRO, chiefly in its Division of Food Research which has grown out of food investigations initiated in 1926 to be one of the largest Divisions. The Division of Food Research undertakes food R&D in the commodity areas: meat, dairy products, fruit, vegetables, fish, poultry and eggs; and also performs strategic research in food science. Additional programs on animal and plant proteins are mounted by the CSIRO Division of Protein Chemistry.

28.3.2 The Division of Food Research does not enter the commodity area of cereals. This area is principally covered by the Bread Research Institute, but also, within CSIRO, by the Wheat Research Unit, which is concerned with wheat and flour quality, and by activities concerned with grain storage in the Division of Entomology, Stored Grain Research Laboratory, and in the Division of Mechanical Engineering. The Division of Horticultural Research undertakes food R&D on dried fruits and wine.

Other Commonwealth establishments

28.3.3 The Armed Forces Food Science Establishment in the Department of Defence conducts food R&D in relation to the needs of the armed forces for compact, lightweight rations of adequate nutritive value, acceptability, and keeping quality. The Australian Government Analytical Laboratories in the Department of Science outlays about \$2.24 million per year on food-related activities but only a small proportion of these activities are research and development.

STATE GOVERNMENTS

28.3.4 The departments of agriculture and of fisheries in the States maintain research activities that are mainly concerned with the production of raw materials for the food and other industries, but some of these activities fall within the area of food R&D as it has been defined.

TERTIARY EDUCATION INSTITUTIONS

28.3.5 The School of Food Technology at the University of NSW is the only university department of this kind in Australia, and it conducts food R&D programs, manned in part by postgraduate students. Minor programs in food R&D arising out of personal interests of staff and supported mainly by external funds are undertaken at the Universities of New England, Tasmania and Melbourne, and at Monash University and the Australian National University. Among the colleges of advanced education, a

significant program in several areas is mounted at Hawkesbury Agricultural College, and minor programs are operative at Queensland Agricultural College, the Royal Melbourne Institute of Technology, and the South Australian Institute of Technology.

INDUSTRIAL RESEARCH ASSOCIATIONS

28.3.6 Three industry research associations (The Bread Research Institute, The Sugar Research Institute and The Australian Wine Research Institute) contribute significantly to food R&D in Australia and in particular to the technical welfare of their respective industries. Some sectors of the industry support research through compulsory levies (see 28.3.14)

INDUSTRIAL LABORATORIES

28.3.7 Only a few of the larger companies in the food industry and the ancillary packaging and supply industries maintain groups truly engaged in food R&D. Many companies have close links with overseas corporations which enable them to draw on results of world-wide R&D. There are many small and medium-sized companies which maintain technical groups only for product development and for production and quality control.

PROFESSIONAL AND OTHER BODIES

28.3.8 There are a number of professional bodies concerned directly or indirectly with food science. They do not conduct or fund research but they contribute to the total research effort by communicating the results of research in conferences and publications, and by recognising research achievement by awards and prizes.

- . Australian Institute of Food Science and Technology (1400 members, 950 professional and 450 sub-professional)
- . Australian Society of Dairy Technology Inc. (1500)
- . Australian Institute of Packaging (280)
- . Nutrition Society of Australia (400)
- . Queensland Society of Sugar Cane Technologists (822)
- . Australian Biochemical Society (1500, 1300 professional)
- . Australian Society for Microbiology Inc. (1200, 900 professional)
- . Royal Australian Chemical Institute, Cereal Chemistry Division (180, 120 professional)

FUNDING

28.3.9 A summary of overall expenditure and funding is presented in Table 28.2.

TABLE 28.2
FUNDING OF FOOD R&D IN AUSTRALIA
(1976-77)

	<u>Expenditure</u> (<u>\$million</u>)	<u>Sources of Funds</u> (<u>\$million</u>)		
		State Govt	Commonwealth Govt.	Industry
CSIRO	8.103	-	6.353 0.875(a)	0.875(a)
Armed Forces Food Science Establishment	0.400	-	0.400	-
State Government	2.400	2.083	0.094(a)	0.094(a)
Fresh Fruit Disinfection Committee		0.064	0.064	
Tertiary Institutions	0.320	-	0.152 0.084(a)	0.084(a)
Research Associations				
BRI	0.622	-	0.143 0.052(a)	0.374 0.052(a)
SRI	1.750	-	0.400	1.350
AWRI	0.355	-	0.094	0.261
Commodity Research Trusts	-	-	1.115(b)	1.115(b)
Food Industry	10.585		1.876	8.709
Rural Credits Development Fund	-		-	0.154
<u>Totals</u>		<u>2.147</u>	<u>10.597</u>	<u>11.963</u>
<u>Grand Totals (c)</u>	<u>24.535</u>		<u>24.707</u>	

(a) These figures are funds provided by the Commonwealth Government and industry (on an approximately 1:1 basis) to Commodity Research Trusts.

(b) These amounts (see Table 28.4) must not be included in totals as they include the amounts designated by (a).

(c) The Grand Totals are not reconciled because procedures used to estimate some of the data are inevitably crude.

FUNDING BODIES

28.3.10 Food R&D in Australia receives support from a number of bodies which disperse funds for research.

Australian Research Grants Committee (ARGC)

28.3.11 The ARGC makes recommendations to the Minister for Science on the funding of research in all disciplines except medicine and dentistry. Commonwealth and State research agencies are not eligible, and grants go mainly to universities. Food R&D receives only a little support from ARGC.

Australian Industrial Research and Development Incentives Board (AIRDIB)

28.3.12 This Board was established under the Industrial Research and Development Incentives Act (1976) which superseded previous legislation of 1967.

28.3.13 Total funds available to AIRDIB for allocation in 1975-76 were \$19.3million. Total grants made to the food and allied industries between 1967 and 1976 by AIRDIB and its predecessor are shown in Table 28.3.

Commodity Research Trusts

28.3.14 Commonwealth legislation has set up a number of commodity research trusts which are financed by levies on the respective industries together with matching Commonwealth grants - see Chapter 19 ('Agriculture'). The majority of projects supported by the trusts are oriented towards production research at the farm level. In some cases the levies support education and market promotion as well as research. Research grants are made on the recommendation of committees made up generally of representatives of the industry, the Australian Agricultural Council, the Commonwealth Department of Primary Industry, the universities, CSIRO and producers. The activities of the commodity research trusts in food research are summarised in Table 28.4.

Rural Credits Development Fund of the Reserve Bank of Australia

28.3.15 The Rural Credits Development Fund was created, and is administered under the Reserve Bank Act, for the promotion of primary production. The grants are made on the advice of a committee drawn from universities and other institutions. Grants for food research made in 1977-78 for periods of one to three years amounted to \$154,000.

28.3.16 Some additional funds are provided by the Australian Apple and Pear Corporation, a statutory body responsible to the Minister for Primary Industry, and the Australian Honey Board.

TABLE 28.3
GRANTS TO THE FOOD AND ALLIED INDUSTRIES
BY THE AUSTRALIAN INDUSTRIAL RESEARCH AND DEVELOPMENT
INCENTIVES BOARD (AIRDIB) AND ITS PREDECESSOR DURING
THE PERIOD 1967 TO 1976

	<u>(\$)</u>	<u>Total (\$)</u>
Food:		
Sugar and sugar preparations	1,127,529	
Cereal preparations, malt and bakery products	1,290,270	
Fruit, meat and vegetable preparations	990,486	
Dairy products including ice-cream	947,766	
Feeding-stuff for animals	637,007	
Margarine, shortening and lard	121,306	
Chocolate and chocolate preparations	133,228	
Fish preparations	98,875	
Other	638,705	5,985,000
Beverages:		
Beer and fermented beverages	510,377	
Distilled beverages	95,399	
Soft drinks and cordials	66,300	
Wine	40,622	
Other	75,528	788,000
Animal, Fish and Vegetable Oils, Fats and Waxes:		
Animal oils and fats	151,511	
Vegetable oils	111,795	263,000
Starches, casein, gelatine, glue, etc.	942,552	943,000
GRAND TOTAL:		<u>7,979,000</u>

TABLE 28.4
COMMODITY RESEARCH TRUSTS : FUNDING OF FOOD R&D

<u>Research Trust Accounts</u>	<u>Annual</u> <u>Grants</u> <u>(\$)</u>
Chicken Meat (1971)	18,000(a)
Dairying (1958)	420,000(a)
Dried Fruit (1971)	55,000(a)
Fishing Industry (1969)	83,000(a)
Meat (1960)	907,000(b)
Pig Industry (1971)	80,000(a)
Poultry Industry (1965)	24,000(a)
Wheat (1957)	625,000(b)
Apple & Pear Corp.(d)	17,000(a)
Honey Board (d)	1,000(a)
Oilseeds (1977)	-
<u>Total</u>	<u>2,230,000(c)</u>

- (a) 1977-78; (b) 1976-77; (c) The Commonwealth contribution is approximately half this figure (see Table 28.2); (d) Statutory body; does not operate a research trust account, but included for completeness.

28.4 DESCRIPTION OF R&D ESTABLISHMENTS

COMMONWEALTH GOVERNMENT

CSIRO

28.4.1 The manpower and money resources of CSIRO for R&D on foods are summarised in Table 28.5.

TABLE 28.5

FOOD R&D IN CSIRO (1976-77)

<u>Division or Unit</u>	<u>Staff</u>			<u>Annual Expenditure (\$)</u>	<u>External Funds (\$)</u>
	<u>Total</u>	<u>Professional</u>	<u>Support</u>		
Division of Food Research					
Headquarters	7	5	2	252,269	
Food Research Laboratory	177	88	89	3,190,373	146,000
Meat Research Laboratory	89	42	47	1,516,604	712,000
Dairy Research Laboratory	69	30	39	1,226,474	270,000
<u>Sub-Total</u>	<u>342</u>	<u>165</u>	<u>177</u>	<u>6,185,720</u>	<u>1,128,000</u>
Division of Protein					
Chemistry	13	10	3	665,150	
Division of Entomology	25	10	15	598,200*	300,000
Wheat Research Unit	17	9	8	322,000	167,000
Division of Mechanical					
Engineering	9	6	3	215,000	120,000
Division of Horticultural					
Research	3	2	1	117,000	35,000
<u>Total</u>	<u>409</u>	<u>202</u>	<u>207</u>	<u>8,103,070</u>	<u>1,750,000</u>

* Refers to 1977-78.

Note: The unit cost per professional worker in these activities of CSIRO is close to \$40,000. A similar calculation for food industry R&D gives a unit cost of \$37,500.

28.4.2 The Division of Food Research operates three main laboratories:

The Food Research Laboratory (FRL) at North Ryde, NSW, erected in 1961, has laboratories for chemistry, biochemistry,

physics, microbiology, plant physiology, and electron microscopy, a series of controlled temperature rooms, a food processing and packaging pilot plant, and facilities for plant growth in controlled environments. A Plant Physiology Unit is maintained in the School of Biological Sciences at Macquarie University.

The Meat Research Laboratory (MRL) at Cannon Hill, Qld, erected in 1967 (Stage I) and 1969 (Stage II), has laboratories for chemistry, biochemistry, physics, microbiology, animal physiology, and electron microscopy, a series of controlled temperature rooms, a meat processing pilot plant, animal handling facilities, and will shortly have an experimental slaughter facility.

The Dairy Research Laboratory (DRL) at Highett, Vic, erected 1955 and extended 1970, has laboratories for chemistry, biochemistry, and microbiology and a comprehensive pilot plant for processing milk products.

In addition the Division maintains a Tasmanian Food Research Unit (staff: 8 total, 5 professional) concerned mainly with seafoods R&D, at the CSIRO Tasmanian Regional Laboratory, Hobart. The Division operates, in conjunction with the NSW Department of Agriculture, the Gosford Horticultural Post-harvest Laboratory.

28.4.3 Within the broad programs approved by the CSIRO Executive the research programs undertaken are determined largely by the Division's own assessment of areas where there is a need for new knowledge, new techniques, or new applications. In making these assessments the Division maintains close contact with the food industry and consumer organisations but only occasionally is a project undertaken as a result of a direct request. The Division's research program is subject to internal review annually, and on several occasions has been reviewed by external committees appointed by the CSIRO Executive.

28.4.4 In addition to its total mission, FRL is the principal Australian centre of expertise in two areas of major, public health significance : food microbiology and the safe processing of canned foods. Another particular area of expertise is the application of combined gas chromatography-mass spectrometry-computer techniques to the identification of volatile compounds derived from foods, of environmental pollutants, and of human and animal secretions of physiological significance. FRL has one of the most advanced mass spectrometer facilities in Australia and is equipped for field desorption spectrometry.

28.4.5 The CSIRO Division of Protein Chemistry, in Parkville, Vic was originally concerned mainly with the proteins of wool, but it has more recently turned its attention to the proteins of muscle and plants.

28.4.6 The CSIRO Division of Entomology, Stored Grain Research Laboratory in Canberra, ACT, was established in 1970 under an agreement between CSIRO and the Australian Wheat Board. The research program is reviewed at least once a year by a Stored Grain Research Liaison Committee on which are represented the Australian Wheat Board, CSIRO,

the Commonwealth Department of Primary Industry, and State Bulk Handling Authorities.

28.4.7 The Wheat Research Unit (WRU), North Ryde, NSW, was established in 1958 to undertake research into the biochemical aspects of wheat and flour quality. It is located within the Bread Research Institute, and operates as one with that Institute.

28.4.8 The CSIRO Division of Mechanical Engineering, Highett, Vic. is limited in its food R&D to engineering aspects of cereal grain storage and drying.

28.4.9 The CSIRO Division of Horticultural Research has laboratories in Adelaide, SA and in Merbein, Vic. Food R&D in this Division is concentrated at the Merbein Laboratory where investigations to assist the dried grape industry began in 1919. It is equipped with pilot-scale plant for dried vine fruits and wine-making.

Department of Defence

28.4.10 The Department of Defence's Armed Forces Food Science Establishment (AFFSE) is in Scottsdale, Tasmania. This is an establishment of the Defence Science and Technology Organisation, and is responsible to the Chief Defence Scientist through the Controller, Services Laboratories and Trials Division. The charter of the AFFSE is to determine the energy and nutrient requirements of Defence Force personnel under the various conditions in which they may be required to operate and to translate these requirements into practical ration scales and ration packs suitable for use under Service conditions (staff: 34 total, 10 professional; budget: \$400,000). AFFSE has well-equipped laboratories and pilot plant, and undertakes production, on a moderate scale, of special ration products which private industry is unable to supply. It has a semi-commercial freeze dryer equipped for cyclic vacuum operation, one of only two in Australia.

Department of Science

28.4.11 The Australian Government Analytical Laboratories, with its head office at Woden, ACT, is part of the Department of Science; it is primarily a service organisation and any R&D is peripheral to the main task of supplying certificates of analysis to client departments. Laboratories are maintained in all States except Queensland. Approximately 70% of the total activities are related to chemical and microbiological analysis of foods. Some research is done on analytical methods, especially for pesticide residues, heavy metals, food additives, and migrant contaminants from plastics (staff: total 230, of which approximately 140 are involved with food work; budget: \$3.2million, of which approximately \$2.2million is spent on food work).

STATE GOVERNMENTS

28.4.12 Manpower and money resources provided by State Governments for food R&D are summarised in Table 28.6. Much of the information is incomplete or imprecise because it has not been possible for the departments to separate food R&D neatly from the activities in agricultural research and extension.

NSW Department of Agriculture

28.4.13 Activities are undertaken at several research centres by this Department:

- . The Division of Horticulture has a major involvement in R&D on the post-harvest handling, treatment, and storage of fruits and vegetables, largely in co-operation with the CSIRO Division of Food Research. The Department and CSIRO jointly operate the Gosford Horticultural Post-harvest Laboratory, with some staff being supported by the Fresh Fruit Disinfestation Sub-Committee.
- . Yanco Agricultural Research Centre, Yanco. Investigations on rice grain quality form an integral part of the overall rice research program. The effects of variety and of management techniques on the quality of rock melons, oranges, peaches, prunes, and potatoes are regularly studied in horticultural research programs.
- . Additional food research work is carried out at the Viticultural Research Station, Griffith, the Horticultural Research Station, Dareton, the Agricultural Research Institute, Wagga Wagga, the Agricultural Research Centre, Tamworth, the Agricultural Research Station, Trangie, and the Poultry Research Station, Seven Hills.

TABLE 28.6
FOOD R&D BY STATE GOVERNMENTS
(1976-77)

Dept and Unit	Staff			Annual Expenditure (\$)	Exterr Fund (\$)
	Total	Professional	Support		
NSW Dept Agr.					
Div. Horticulture	14	7	7	248,000	74,00
Agr. Res. Centre, Yanco	2	1	1	na	10,00
Vit. Res. Stn, Griffith	2	1	1	na	
Hort. Res. Stn, Dareton	na	na	na	na	
Agr. Res. Inst., Wagga	6	2	4	na	
Agr. Res. Centre, Tamworth	na	na	na	na	
Agr. Res. Stn, Trangie	na	3	na	na	33,00
Poultry Res. Stn	na	na	na	na	
<u>Sub-Total</u>	<u>24(a)</u>	<u>14(a)</u>	<u>13(a)</u>	<u>500,000(b)</u>	<u>84,000</u>
NSW Health Commission	<u>8</u>	<u>5</u>	<u>3</u>	<u>100,000</u>	-
Qld Dept Prim. Ind.					
Food Pres. Res. Lab.	35	16	19	564,000	26,600
Dairy Res. Lab.	26	13	13	326,000	46,000
Animal Ind. Div.	12(c)	6(c)	6(c)	94,000	1,700
Animal Res. Inst.	3(c)	2(c)	1(c)	na	
<u>Sub-Total</u>	<u>76</u>	<u>37(a)</u>	<u>33(a)</u>	<u>1,000,000(b)</u>	<u>74,300</u>
Vic. Dept Agr.					
Inst. Dairy Tech.	30(c)	13(c)	17(c)	800,000(c, d)	71,000
Pastoral Res. Stn	3	1	2	15,000	-
Animal Res. Inst.	5	2	3	15,500	15,500
Wheat Res. Inst.	na	na	na	na	-
Mildura Res. Stn	na	na	na	na	-
<u>Sub-Total</u>	<u>38</u>	<u>16</u>	<u>22</u>	<u>600,000</u>	<u>86,500</u>
	(a, c)	(a, c)	(a, c)	(b)	
SA Dept Agr. Fish.	6	4	2	100,000(b)	
WA Dept Agr.	3	2	1	75,000(b)	22,000
Tas Dept Agr.	1	1	-	25,000(b)	17,500
<u>Total</u>	<u>156</u>	<u>79</u>	<u>80</u>	<u>2,400,000</u>	<u>317,300</u>
	(a, c)	(a, c)	(a, c)		

(a) Incomplete; (b) Estimated; (c) Not all food R&D; (d) 1977-78; (e) na = not available.

Note: For transfer to Table 28.8, the External Funds are assumed to be provided by the Fresh Fruit Disinfestation Committee (\$128,000, Table 28.1) and the Commodity Research Trusts (\$189,000).

Queensland Department of Primary Industries

28.4.14 This Department conducts research programs in the following establishments:

- . The Sandy Trout Food Preservation Research Laboratory, Hamilton. This Laboratory, established in 1960, within the Horticulture Branch of the Division of Plant Industry is concerned with the composition, quality, storage and processing of primary products, particularly fruits and vegetables. Facilities include cold rooms and a pilot plant for food processing and wine making.
- . The Otto Madsen Dairy Research Laboratories, Hamilton. This Laboratory, opened in 1967, provides technical service and R&D facilities for the primary and secondary sections of the dairying industry, and also has some responsibilities for seafoods.
- . Additional research work is carried out at the Biochemistry Branch of the Animal Industry Division and the Pathology Branch of the Animal Research Institute, Yeerongpilly.

Victorian Department of Agriculture

28.4.15 This Department carries out food R&D in several establishments.

- . The Gilbert Chandler Institute of Dairy Technology, Werribee (1968) undertakes R&D for the manufacturing section of the dairy industry. The pilot dairy factory is unequalled in any other dairy research institute in Australia.
- . The Pastoral Research Station, Hamilton, Vic conducts programs concerned with beef carcass quality.
- . Additional research work is carried out at the Horticultural Research Institute, Knoxfield, The Animal Research Institute, Werribee, The Wheat Research Institute, Horsham, and the Mildura Research Station, Irymple.

South Australian Department of Agriculture and Fisheries

28.4.16 The Horticulture Branch of the Department has a Post-harvest Research Group based at Northfield Research Laboratories.

Western Australian Department of Agriculture

28.4.17 This Department carries out mainly production research, with only a small component of work in dairy products and fruit and vegetable storage. The Department is about to commence research on meat quality and storage.

TERTIARY EDUCATION INSTITUTIONS

University of NSW

28.4.18 A Department of Food Technology was established in 1952 within the School of Chemical Engineering; in 1976 it became the School of Food Technology. Manpower and money resources are summarised in Table 28.7 together with those for all other tertiary institutions. This School conducts a wide-ranging program with special expertise in the areas of food microbiology (notably in relation to poultry and seafoods), milk products, the physiology and chemistry of fruits and vegetables, cereals, and fermented beverages. In addition, the University has set up a company, Unisearch Ltd, which undertakes R&D contracts including those in the food area.

University of New England

28.4.19 In the Department of Animal Science there are R&D programs on carcass quality, based on facilities for maintaining live cattle and handling carcasses, and laboratories for studies on meat muscle chemistry and histology.

University of Tasmania

28.4.20 The Departments of Agricultural Science and Mechanical Engineering conduct some work on food microbiology and on dehydration. They maintain close relations with the CSIRO Tasmanian Food Research Unit.

Monash University

28.4.21 The School of Chemical Engineering maintains projects on malt extraction and on biological treatment of food wastes and effluents.

Australian National University

28.4.22 In the John Curtin School of Medical Research, the Protein Chemistry Group conducts research on genetic variants of milk proteins; this is relevant to technological properties.

Hawkesbury Agricultural College (HAC)

28.4.23 Food R&D is carried out in the Department of Food Technology, School of Food Sciences with some joint projects with other departments. Facilities include a modern, semi-commercial dairy products processing plant and an exceptionally spacious and well-equipped food processing pilot plant built at a cost of \$1.25million. The Dairy and Horticultural Research Centres of the NSW Dept of Agriculture are located on the College campus and CSIRO and ICI Australia Ltd have stationed research staff at the College.

Queensland Agricultural College (QAC)

28.4.24 Some work is carried out in the Departments of Food Technology and Poultry Technology, where the facilities include a food processing pilot

plant, and a poultry processing plant with a capacity of 450 birds per hour.

TABLE 28.7
FOOD R&D IN TERTIARY EDUCATIONAL INSTITUTIONS
(1976-77)

Institution	Staff on Food R&D			Research	External
	Academic	Support	Post-graduate Workers	Expenditure(b)	Funds(c)
				\$	\$
Univ.NSW	11	8	48	40,000	31,000
Univ.New Eng.	2	3	2	10,000	8,000
Univ.Tas.	3	1	2	20,000	20,000
Univ.Melbourne	3	na	na	29,000	29,000
Monash Univ.	4	1	1	3,000	-
Aust.Nat.Univ.	2	1	1	10,000	-
HAC	17	5	-	79,000	69,000
QAC	1	1	-	400	-
RMIT	4	na	9	5,000	Some
SAIT	2	2	na	11,500	11,000
Total :	49			207,900	168,000
Adjusted Total(a)				320,000	

(a) It is difficult to provide a reliable estimate of expenditure in this area because academic salaries are generally not accounted for; in addition, involvement of academic staff is usually part-time. To estimate the total R&D expenditure it was assumed that academic staff spend one-third of time on R&D, and that cost per academic worker is \$20,000 p.a., i.e. rather less than government or industry because of the component of student labour. Thus 49 professionals gives a total of \$320,000.

(b) Academic salaries are not included.

(c) The external funds come mainly from Commodity Research Trusts (Table 28.4) and therefore are roughly half Commonwealth Government, half industry funds. They are accounted for in the Adjusted Total (a)

Royal Melbourne Institute of Technology (RMIT)

28.4.25 The Food Science and Technology section of the Department of Applied Chemistry is involved with projects arising from industrial inquiries to Technisearch Pty Ltd, a company formed in 1971 to coordinate R&D which RMIT conducts for outside bodies on a contract basis.

South Australian Institute of Technology (SAIT)

28.4.26 In the School of Chemical Technology there are microbiological laboratories equipped for research in food microbiology and in treatment of wastes.

INDUSTRIAL RESEARCH ASSOCIATIONS

The Bread Research Institute (BRI)

28.4.27 The laboratories of the BRI are located on the CSIRO site at North Ryde, NSW. They are well equipped for cereal research and include pilot-scale milling and baking facilities (staff: 45 total, 19 professional); all details on expenditure and source of funds are summarised in Table 28.2. BRI is the main research centre in Australia concerned with the science and technology of wheat utilisation; it incorporates and administers the CSIRO Wheat Research Unit. It also functions as the Central Grain Research Laboratory for the Australian Wheat Board, for which it provides all scientific services required in the handling and marketing of the Australian wheat crop. A division of the Institute is concerned with education and research on nutrition and with consumer services.

The Sugar Research Institute (SRI)

28.4.28 The SRI occupies substantial laboratories (fixed assets, at cost, \$1.65million) in Mackay, Qld, which are well-equipped with chemical, pilot-plant, engineering and computer facilities (staff: 56 total, 25 professional). The research program covers all aspects of raw sugar production and includes cane harvesting and transport as they affect the processing of cane in the factory and the quality of the raw sugar. SRI cooperates with CSIRO Division of Chemical Technology on utilisation of bagasse. An ecological study at the James Cook University of the impact of raw sugar mills on North Queensland streams is wholly supported by SRI.

The Australian Wine Research Institute (AWRI)

28.4.29 AWRI is housed in well-equipped laboratories (fixed assets, at cost, \$420,000) located on land leased from the University of Adelaide at Urrbrae, SA (staff: 17 total, 11 professional). The research program is directed towards the understanding and control of factors influencing the composition of wines and brandies with a view to improving their quality, simplifying production processes, and enhancing their market value. A confidential technical service is provided to winemakers on immediate problems.

INDUSTRIAL LABORATORIES

28.4.30 In Table 28.8 companies in the food industry have been arranged approximately in order of their contribution to food R&D. Three companies maintain total staffs on food R&D in excess of 50:

28.4.31 CSR Ltd maintains three main R&D establishments:

CSR Research Laboratories, Roseville, NSW, (staff:22) carries out R&D for all Divisions of the company - the Sugar Division, the Minerals and Chemicals Division, and the Building and Construction Materials Division. Re-organisation currently under way is devolving direct responsibility for R&D to the three CSR divisions.

- . The Technical Development Department of the Sugar Division, Sydney, (staff: 25 total) is responsible for R&D on processing, engineering, and automation.
- . The CSR Central Laboratory has mainly a quality control function but maintains a research section (Staff:7).

The major R&D programs are concerned with sugar milling and refining, distillery products, utilisation of by-products and macadamia nut processing.

28.4.32 Kraft Foods Ltd, Melbourne, maintains a substantial R&D Laboratory with a staff of 56. Major emphasis is on dairy products, yeast extracts, packaging, and product development. Kraft has established a reputation for expertise in the microbiology, chemistry, and biochemistry of food.

28.4.33 Mauri Bros & Thomson Ltd (MBT). Most work is carried out at MBT Research Laboratories, North Ryde, NSW, with additional activities in MBT Flavours and Additives Co, Homebush, NSW, Yeast Co of Australia, Waterloo, NSW, Barretts Food Co, Richmond, Vic., and Queensland Can Company, Rocklea, Qld. The programs cover a wide area and include cheese starters, yeast and bakery technology, food flavours, and product development (R&D staff: 55).

28.4.34 Unilever Australia Pty Ltd, Balmain, NSW, maintains a Central Research Laboratory which carries out research of a relatively fundamental nature for seven companies in the group. Approximately 45% of the effort is concerned with edible lipids. Edible Oil Industries Pty Ltd, Balmain, operates a Development Department conducting R&D on oils and fats, baking technology, and packaging. Rosella Foods Pty Ltd, Richmond, Vic., has a Unit mainly engaged on the processing and packaging of convenience foods (R&D staff: 32).

28.4.35 The major programs in the cereals area are undertaken by Arnott's Biscuits Pty Ltd, Homebush, NSW (staff: 34), and Fielders Ltd, Sydney (staff: 24). Carlton and United Breweries Ltd, Melbourne (staff: 24) mount the largest effort on cereal-based fermented beverages.

TABLE 28.8
R&D IN THE FOOD INDUSTRY
(1976-77)

<u>Company</u>	<u>Staff</u>			<u>Expenditure</u> <u>(\$million)</u>
	<u>Total</u>	<u>Professional</u>	<u>Support</u>	
CSR (d)	58	39	19	
Kraft Foods (a)	56	34	22	
Mauri Bros & Thomson (d)	55	30	25	
Unilever (a,d)	23	13	10	
Rosella Foods(a,d)	9	5	4	
Arnotts Biscuits (d)	34	14	20	
Fielders (d)	24	10	14	
Carlton & United Breweries	24	10	14	
H.J. Heinz Co. Aust. (a,d)	18	11	7	
CIG (b)	12	10	2	
Provincial Traders (d)	12	5	7	
Master Foods of Australia(a,d)	11	5	6	
Davis Gelatine (Aust.)	10	7	3	
Australian Iron & Steel (d)	9	4	5	
Lactos	9	4	5	
Edgell	8	2	6	
Wrightcel (a,d)	7	5	2	
SAFCOL (d)	7	4	3	
SA Brewing Co.	7	3	4	
Keith Harris	7	2	5	
Bush Boake Allen (a,d)	6	4	2	
QUF Industries (d)	6	6	0	
Kimpton, Minifie & McLennon Ltd	6	4	2	
Tooth & Co.	5	5	0	
Unigate Aust. (a)	5	2	3	
Cerebos (Aust.) (a,d)	4	2	2	
Golden Circle (d)	4	2	2	
A.W. Allen (d)	4	1	3	
Dairy Farmers	4	2	2	
Tooheys Ltd.	3	3	0	
N.B. Love (b)	3	2	1	
Gadsden (d)	3	2	1	
Sara Lee (a)	2	1	1	
Hunter Valley (d)	2	1	1	
Others	60(e)	27(e)	33(e)	
<u>Total</u>	<u>517</u>	<u>281</u>	<u>236</u>	<u>10.59</u>
			less(c)	<u>1.88</u>
				<u>8.71</u>

(a) complete foreign ownership; (b) partial foreign ownership; (c) the deduction for Australian Industrial Research and Development Incentives Board (AIRDIB) contribution; (d) have received AIRDIB grants or payments since July 1976 'owing' from the preceding Act; (e) estimated.

28.4.36 H.J. Heinz Co. Australia Ltd, Melbourne, (staff: 19) represents the many companies working on the formulation, process and package

development for processed foods. Among companies engaged only in packaging, Wrightcel Ltd (staff: 7) mounts a substantial program related to food packaging. Commonwealth Industrial Gases (CIG) Ltd maintains substantial programs (staff: 12, expected to increase to 22 in 1977-78) on treatment of waste waters from the food industry.

28.5 DESCRIPTION OF MAJOR R&D PROGRAMS

28.5.1 In this section, major programs in food R&D in Australia are described under a number of broad headings: first those specific to each of the principal commodity groups, and then some programs that are general to many commodity groups. All programs must be understood to be continuing unless it is stated otherwise. Programs costing less than about \$50,000 per year are described as minor programs and details are not given. Quantitative information on the distribution of resources is consolidated in Table 28.9.

ANIMAL FOODS

Beef and sheep meats

28.5.2 In the area of carcass quality, representing the interface between animal production and animal foods, programs on the relations between carcass conformation and composition and meat quality, and on the development of objective systems for the classification of carcasses, are in progress at the Universities of Melbourne and New England, the Departments of Agriculture in NSW and Tasmania, the Queensland Department of Primary Industries, and the Australian Meat and Livestock Corporation. The marketing implications of standardised sheep carcass classification are being studied by the Bureau of Agricultural Economics. All these programs are funded by the Australian Meat Research Committee to the amount of \$179,000 in 1977-78.

28.5.3 The CSIRO Meat Research Laboratory (MRL) which maintains programs on muscle properties, is studying the biochemistry and structure of muscle in relation to the properties of meat, in particular the role of proteins and minor components in muscle metabolism and contraction (staff: 15 total, 9 professional; budget: \$370,000). The CSIRO Food Research Laboratory (FRL) is applying differential calorimetry to study muscle, connective tissue, and isolated meat proteins. Meat proteins are also the subject of research at the CSIRO Division of Protein Chemistry with emphasis on the use of biophysical methods such as x-ray diffraction and measurements of infra-red dichroism to examine the structure of collagen (staff: 5 total, 3 professional; budget \$187,400).

TABLE 28.9
MAJOR FOOD R&D PROGRAMS IN AUSTRALIA
DISTRIBUTION OF RESOURCES(a)
(1976-77)

Major Programs	No. of Labs(c)	Total	Professional	Staff	Support	Annual Cos (\$million)
ANIMAL FOODS						
Beef and sheep meats						
Carcass quality	7	31	21	10		0.179
Muscle properties	3	23	14	9		0.635
Preservation and storage	2	17	9	8		0.356
Processing	2	20	13	7		0.475
Industry problems	2	32	17	15		0.718
Sub-total	13	123	74	49		2.363
Pig meats	2	na	na	na		0.080
Poultry meats and eggs	5	19	10	9		0.092
Total	16	142	84	58		2.535
DAIRY FOODS						
Milk fractions	7	41	23	18		0.519
Cheese etc.	8	63	36	27		1.379
Quality aspects	1	5	4	1		0.150
Milk processing	4	56	29	27		1.041
Product development	6	33	19	14		0.705
Total	15	198	111	87		3.794
SEAFOODS	Total	7	32	14	18	0.383
FRUITS & VEGETABLES						
Storage	8	63	31	32		1.232
Strategic research	1	14	9	5		0.238
Processing	8	37	18	19		0.989
Total	13	114	58	56		2.459
CEREALS etc.						
Storage	3	35	17	18		0.824
Quality aspects	3	17	7	10		0.330
Biochemistry	3	31	13	18		0.487
Technology	8	71	35	36		1.545
Cassava	1	10	5	5		0.213
Total	14	164	77	87		3.399
OIL-SEEDS etc.						
Raw materials	4	6	5	1		0.070
Edible fats	34	39	20	19		0.690
Plant proteins	4	24	21	11		0.589
Total	12	69	38	31		1.349

<u>SUGAR</u>					
Harvesting	1	8	6	2	0.211
Milling	4	69	41	28	1.585
Refining	1	21	14	7	0.528
<u>Total</u>	<u>4</u>	<u>98</u>	<u>61</u>	<u>37</u>	<u>2.324</u>
<u>FERMENTED BEVERAGES</u>					
Grape-based	4	21	14	7	0.490
Cereal-based	4	39	21	18	0.628
Sugar-based	1	4	3	1	0.120
<u>Total</u>	<u>9</u>	<u>64</u>	<u>38</u>	<u>26</u>	<u>1.238</u>
<u>FOOD QUALITIES</u>					
Nutritive aspects	4	27	16	11	0.460
Structure	4	15	9	6	0.313
Flavour	5	32	21	11	0.843
<u>Total</u>	<u>9</u>	<u>74</u>	<u>46</u>	<u>28</u>	<u>1.616</u>
<u>FOOD MICROBIOLOGY</u>					
<u>Total</u>	<u>6</u>	<u>29</u>	<u>17</u>	<u>12</u>	<u>0.341</u>
<u>FOOD SAFETY</u> <u>Total</u>	<u>5</u>	<u>19</u>	<u>11</u>	<u>8</u>	<u>0.307</u>
<u>FOOD ENGINEERING</u> <u>Total</u>	<u>5</u>	<u>18</u>	<u>12</u>	<u>6</u>	<u>0.347</u>
<u>FOOD PACKAGING</u> <u>Total</u>	<u>8</u>	<u>45</u>	<u>26</u>	<u>19</u>	<u>1.039</u>
<u>PRODUCT DEVELOPMENT</u>					
Industry	10	69	38	31	1.383
Armed Forces	1	34	10	24	0.400
<u>Total</u>	<u>11</u>	<u>103</u>	<u>48</u>	<u>55</u>	<u>1.783</u>
<u>WASTE CONTROL</u> <u>Total</u>	<u>4</u>	<u>17</u>	<u>11</u>	<u>6</u>	<u>0.391</u>
<u>GRAND TOTAL(b)</u>	<u>84</u>	<u>1,186</u>	<u>652</u>	<u>534</u>	<u>23.305(b)</u>

(a) Estimates used in some cases where information not available. (b) The Grand Total is not reconciled with the Grand Totals in Table 28.2 because procedures used to estimate some of the data are inevitably crude. (c) The totals at the end of each section take into account the contributions of a single laboratory to more than one field of research.

28.5.4 In the area of meat preservation and storage, the technology of cold storage of meat including vacuum-packed meat, the microbiology of hot-boned meat, and the ecology of meat spoilage bacteria are the subjects of a major program at MRL (staff: 15 total, 8 professional; budget: \$349,000). There is a minor program at the University of NSW.

28.5.5 MRL is investigating meat processing and in particular the mechanical separation of meat from bones, the mechanical properties of meat, and the recovery of pharmaceuticals from abattoir by-products (staff: 18 total, 12 professional; budget: \$435,000). There is a minor program on cured meat technology at Mauri Brothers and Thompson Research Laboratories.

28.5.6 The Industry Section of MRL studies meat industry problems and provides a service to the meat industry in investigation of short-term problems in meat analysis, technology, hygiene, and treatment of wastes (staff: 20 total, 10 professional; budget: \$458,000).

28.5.7 Product and process development on gelatine and collagen, and basic research on properties and composition of gelatine are undertaken by Davis Gelatine (Australia) Pty Ltd (staff: 12 total, 7 professional).

Pig meats

28.5.8 A pig carcass measurement and information service in all States is coordinated by NSW Dept of Agriculture, and the Australian Meat and Livestock Corporation is working on automatic equipment for pig carcass classification.

Poultry meats and eggs

28.5.9 Minor programs on pasteurisation of poultry and tenderness of poultry are conducted at the University of NSW and Queensland Agricultural College (QAC).

28.5.10 Minor programs on composition, quality, functional properties, and technology of eggs and egg products are mounted at the University of NSW, the Egg Marketing Board of NSW, the Victorian Department of Agriculture and FRL.

DAIRY FOODS

Milk fractions

28.5.11 The CSIRO Dairy Research Laboratory (DRL) is studying milk fractions and in particular the biochemistry and microstructure of milk proteins, their reactions with rennin, and the production and recovery of rennin (staff: 10 total, 6 professional; budget: \$333,000). The Australian National University has a program on milk proteins with application to problems of heat stability. The structure of milk fat and its utilisation in spreads and in baking are areas of research at the Queensland Butter Board, the Gilbert Chandler Institute of Dairy Technology (Werribee), and Lactos Pty Ltd. The utilisation of lactose also is being studied at Werribee and at Hawkesbury Agricultural College (HAC). A program on continuous enzymic conversion of lactose in milk at the University of NSW has led to development and nutritional evaluation of lactose-free dairy products by Sharpe Research Pty Ltd (staff: 6 total, 3 professional).

Cheese and fermented dairy products

28.5.12 Many aspects of cheese technology and microbiology, especially starter cultures and factors affecting flavour, are being studied at DRL (staff: 8 total, 4 professional; budget: \$267,000). Major programs on cheese and whey technology and microbiology, including cheese starters and bacteriophage, are conducted by Kraft Foods Ltd (staff: 30 total, 19 professional). Mauri Brothers and Thompson Research Laboratories have

undertaken commercial development of a process for concentrated cheese starters which was initiated by CSIRO Dairy Research Laboratory (DRL). This venture by a company wholly-owned in Australia is abreast with world developments (staff: 6 total, 5 professional). Minor programs on cheese technology and microbiology are mounted by the Gilbert Chandler Institute at Werribee, Lactos Pty Ltd, QAC, and Dairy Farmers Co-operative Ltd, and on yoghurt at the University of NSW. The chemistry of flavour in cheddar cheese, Feta cheese, and heated butter is being studied by DRL (staff: 5 total, 4 professional; budget: \$150,000).

Milk processing

28.5.13 In the area of milk processing, the treatment of whey by ultra-filtration, the properties of whey proteins, the functional properties of dairy products and their use as food ingredients are aspects of a major program at DRL (staff: 19 total, 11 professional; budget: \$646,000). Another major program, at Otto Madsen Dairy Research Laboratories involves processed products from milk fats and proteins, vegetable oil/butter blends, and milk concentrate and powders (staff: 26 total, 13 professional; budget: \$326,000). Minor programs on milk processing are conducted by the Gilbert Chandler Institute at Werribee and by the Western Australian Department of Agriculture.

28.5.14 A major program on product and process development of dairy foods is mounted by Kraft Foods Ltd. Extension of the shelf life of perishable dairy foods is being investigated by QUF Industries Ltd (staff: 5 professional). Minor programs in product development of dairy foods are conducted by Dairy Farmers Co-operative Ltd and Hunter Valley Co-operative Dairy Co. Ltd.

SEAFOODS

28.5.15 Fish piece products from less-favoured Australian species is a major field of study at the CSIRO Tasmanian Food Research Unit (TFRU) (staff: 7 total, 4 professional; budget: \$185,000). This is allied to a project at Hawkesbury Agricultural College (HAC) on the functional properties of fish proteins. TFRU is also investigating metal contamination of seafoods, and lobster processing. The microbiology of prawns, oysters, and crabs is being studied at the Otto Madsen Dairy Research Laboratories and the University of NSW, and the Queensland Department of Primary Industries, Animal Industry Division, is working on kerosene taint in mullet. Product development from seafoods is undertaken by South Australian Fishermen's Co-operative Ltd (staff: 7 total, 4 professional) and NSW Fisheries Department.

FRUIT AND VEGETABLES

Storage

28.5.16 Investigations at FRL are concerned with the storage of bananas, apples, avocados, rock melons, and tomatoes at low pressures and in

ethylene-free atmospheres. An area of particular interest is the tolerance of whole plants and fruits to low temperatures, in the field or in cool storage, and with related studies of the structure of membranes and the behaviour of enzyme systems (staff: 15 total, 8 professional; budget: \$490,000). The Gosford Post-harvest Horticultural Laboratory is concerned with control of fungal wastage of fruits, disinfestation of fruits against Queensland fruit fly, and storage studies on potatoes, sweet potatoes and onions (staff: 9 total, 4 professional; budget: \$141,000). Further programs on the quality and storage technology of fruits and vegetables are conducted by the Sandy Trout Food Preservation Research Laboratory (staff: 11 total, 7 professional; budget: \$225,000), the South Australian Department of Agriculture and Fisheries (staff: 6 total, 4 professional), the Victorian Department of Agriculture (staff: 9 total, 4 professional), the Western Australian Department of Agriculture (staff: 3 total, 2 professional), and the University of NSW (staff: 8 total, 2 professional). Disinfestation studies are also undertaken by the Queensland, Western Australian, and Tasmanian Departments of Agriculture.

Strategic research in plant physiology

28.5.17 Protein synthesis in leaf cells, and membrane structure and function in relation to temperature, are the significant areas of research in the FRL Plant Physiology Unit (staff: 14 total, 9 professional; budget \$238,000).

Processing of fruits and vegetables

28.5.18 Factors influencing the quality of citrus fruits and citrus products are being studied at FRL with particular interest in bitter principles and treatments for the removal of the latter from citrus juice (staff: 4 total, 3 professional; budget: \$205,000). Other programs at FRL are concerned with drying of hops and of tree and vine fruits, and with the processing of vegetables and apple products (staff: 6 total, 3 professional; budget \$152,000). Investigations on dried vine fruits are also carried out by the CSIRO Division of Horticultural Research, as well as by the NSW and SA Departments of Agriculture. Major programs on the development of new techniques and products for processed fruits and vegetables are undertaken by the Sandy Trout Food Preservation Research Laboratory (staff: 9 total, 4 professional), Golden Circle Cannery (staff: 4 total, 2 professional), and Edgell Division of Petersville (staff: 7 total, 3 professional). CSR Ltd maintains a program on processing macadamia nuts.

CEREALS AND OTHER CARBOHYDRATE SOURCES

Storage

28.5.19 The CSIRO Stored Grain Research Laboratory (staff: 25 total, 10 professional; budget: \$600,000), conducts major programs to investigate alternative pesticides to those to which insects are becoming resistant, and to develop grain storage systems which inhibit proliferation of pests, e.g. controlled atmosphere storage. An allied program in the CSIRO Division of Mechanical Engineering seeks to achieve similar ends by either refrigeration of grain to inhibit insect growth, or by heating grain to

destroy insects (staff: 9 total, 6 professional; budget: \$215,000). A minor program on aeration of grain is undertaken at the University of NSW.

Quality of grains and flours

28.5.20 The Bread Research Institute (BRI) undertakes wheat quality evaluation in connection with breeding programs, variety trials, and wheat shipments and it investigates rapid methods for quality prediction (staff: 7 total, 3 professional). There are related activities on grain sampling and the identification of cereal cultivars in the CSIRO Wheat Research Unit (WRU) (staff: 6 total, 2 professional; budget: \$122,360). Development of wheat and flour products with optimum properties for use in packaged foods is undertaken by Kimpton, Minifie and McLennon Ltd (staff: 6 total, 2 professional).

Biochemistry of cereals

28.5.21 WRU is studying the biochemistry of the developing wheat grain and of grain hardness, the genetic control of wheat and barley proteins, allergic responses to cereal proteins, and the production and utilisation of gluten (staff: 10 total, 6 professional; budget: \$200,000). A major program on the starch and gluten fractions of cereals and on products derived from these fractions is mounted by Fielders Ltd (staff: 14 total, 5 professional), and there is a corresponding minor program at the University of NSW.

Technology

28.5.22 High extraction rate flourmilling, controlled dough development, dough mixing, frozen doughs, bakery oils, and milk and whey products in breadmaking are areas of applied R&D at BRI (staff: 10 total, 5 professional; budget: \$192,000). A major program of product, process, and packaging R&D on cereal foods, especially biscuits and related foods, is mounted by Arnotts Biscuits Pty Ltd (staff: 34 total, 14 professional). Development of new aids to breadmaking is a major program at Mauri Brothers and Thompson Research Laboratories and Barretts Food Company (staff: 10 total, 6 professional), and the associated Yeast Company of Australia is working on development of a dried yeast with high activity and good keeping quality (staff: 4 total, 3 professional). A minor program on baking technology is undertaken by N.B. Love Industries Pty Ltd.

Other carbohydrate crops

28.5.23 A major program on the production and processing of cassava in Australia as a source of starch and derived products is conducted by Fielders Ltd (staff: 10 total, 5 professional). Utilisation of triticale (a hybrid of wheat with rye) in manufactured foods is the subject of a program at the Queensland Agricultural College.

OIL SEEDS AND HIGH PROTEIN SEEDS

Raw materials

28.5.24 CSIRO Division of Plant Industry conducts programs on the breeding of protein-oil crops and on the conversion of linseed into a source of edible oil (staff: 2). The Division receives a supplementary grant of \$21,000 from the Rural Credits Development Fund (RCDF). Hawkesbury Agricultural College (HAC) has joined with plant breeders at the University of Sydney and the NSW Department of Agriculture to develop improved soybean varieties for use as human food. There are four part-time staff, three of which are professionally qualified. A supplementary grant of \$39,000 is received from the RCDF.

Edible fats

28.5.25 Major programs on product and process development with edible fats and oils are undertaken by Edible Oil Industries Pty Ltd (staff: 16 total, 8 professional), and Provincial Traders Ltd (staff: 12 total, 5 professional); and on more basic aspects of lipid research concerned with autoxidation in relation to keeping quality, and physical chemistry in relation to performance, by Unilever Australia Pty Ltd (staff: 7 total, 5 professional).

Plant proteins

28.5.26 The composition, structure, and characteristics of plant proteins as they relate to the functioning of the plant and their use as foods for monogastric animals, including man, is a major research area in the CSIRO Division of Protein Chemistry (staff: 8 total, 7 professional; budget: \$484,000). Assessment of the suitability of vegetable protein foods produced in Australia, for preparation of new food forms by extrusion, is a project at FRL (staff: 2 professional; budget: \$92,000). A program on sweet lupin and soy proteins is in progress at the University of NSW.

SUGAR

Harvesting

28.5.27 Sugar cane harvesting and transport is a fringe area where food R&D extends into the engineering and economics of field production of the crop. A major program at the Sugar Research Institute (SRI) (staff: 8 total, 6 professional), embraces mechanical harvesting trials in green and burnt cane and engineering studies of railways and vehicles used for transporting cane.

Milling

28.5.28 At SRI there is also a major program on various aspects of sugar milling: flocculation, molasses exhaustion, enzymic and microbial problems, bagasse utilization, and computer simulation of a sugar mill (staff: 36 total, 19 professional). CSR Ltd, in several laboratories, mounts another major program concerned with processes for improving sugar recovery and quality, and for minimising pollution and waste.

Refining

28.5.29 A program on improved processing procedures, new methods for removal of impurities, and new refined sugar products is undertaken by CSR Ltd.

FERMENTED BEVERAGES

Grape-based beverages

24.5.30 The major program in this area is conducted by the Australian Wine Research Institute and embraces investigations on the volatile components of wine and distilled products, the non-volatile constituents in wines, oxidation in white wines, and wine microbiology (staff: 10 total, 9 professional). The Institute also maintains a 'trouble-shooting' service to the Australian wine industry. Minor programs are undertaken by the CSIRO Division of Horticultural Research, the Sandy Trout Food Preservation Research Laboratory, and the University of NSW.

Cereal-based beverages

28.5.31 Investigations on the effects of raw materials and of the fermentation process on beer quality, and on the analytical characterisation of beer flavour and stability, are undertaken by Carlton and United Breweries Ltd (staff: 24 total, 10 professional). Programs are also mounted by South Australian Brewing Company Ltd on low-alcohol beers and the shelf stability of beers (staff: 7 total, 3 professional); by Tooth & Company Ltd on the recovery of wort and beer, on vertical fermenters, and on utilisation of by-products (staff: 5 professional); and by Tooheys Ltd on barley brewing and high-gravity brewing (staff: 3 professional).

Sugar-based beverages

28.5.32 CSR Ltd is studying improved procedures and control for molasses fermentation and for disposal and utilisation of distillery wastes and byproducts.

FOOD QUALITIES

Nutritive aspects

28.5.33 Investigations at FRL embrace the metabolism of lipids including conjugated fatty acids, the relation of biotin to stress syndromes, the synthesis of biotin by gut microflora, the occurrence of biogenic amines and salicylates in foods, and the adsorption of bile salts by dietary fibre (staff: 16 total, 11 professional; budget: \$385,000). Minor programs in this area are conducted at the Bread Research Institute (BRI), Hawkesbury Agricultural College (HAC), and the University of NSW.

28.5.34 The nature of water in biological systems and the rheological properties of soft solids is being studied at FRL (staff: 12 total, 7

professional; budget: \$275,000). BRI is investigating the rheology of dough, the University of NSW the properties of carrageen gums, and Kraft Foods Ltd the rheology of yeast extracts.

Flavour

28.5.35 A major program at FRL involves application of advanced mass spectrometric techniques, such as field desorption and multiple ion monitoring, to identify flavour compounds and other components of foods; there are also studies of olfaction in humans and animals (staff: 10 total, 8 professional; budget: \$513,000 which includes a special grant of \$241,000 for a mass spectrometer). Flavour studies on butter and cheese have been referred to under 'Dairy Foods'. A program on development of artificial flavours for the food industry is conducted by Mauri Brothers and Thompson Research Laboratories Flavours and Additives Company (staff: 7 total, 5 professional), and analogous programs on natural and synthetic flavours by Bush Boake Allen Australia Ltd (BBA) and Keith Harris and Company Ltd. Studies on Tasmanian peppermint oils are in progress at BBA and at the University of Tasmania.

FOOD MICROBIOLOGY

28.5.36 The major program in this area is conducted by FRL; it covers methods for detecting food poisoning organisms, properties of bacterial spores, viruses in foods, microflora of the human gut, and food mycology (staff: 14 total, 10 professional; budget: \$282,000). Significant contributions to methodology in food microbiology, and mycotoxin studies are made by Kraft Foods Ltd. Mycotoxin-producing fungi are also studied by Queensland Department of Primary Industries, Animal Industry Division. Programs on the microbiology of chickens and oysters are undertaken at the Universities of Tasmania and NSW, and at the latter university on prepared frozen foods and hospital foods also.

28.5.37 In a joint project, the University of Sydney School of Chemical Engineering and HAC are investigating the utilization in human foods of yeasts grown on starch substrates. Other programs in food microbiology have been mentioned under the commodity groups; 'Animal Foods', 'Dairy Foods', 'Seafoods', and 'Fermented Beverages'.

FOOD SAFETY

28.5.38 In this area are included programs on trace elements in foods at the Health Commission of NSW and J. Gadsden Pty Ltd (some projects have been mentioned under 'Seafoods'); on residues of pesticides and sterilants in foods at the Health Commission of NSW, Queensland Department of Primary Industries, Animal Industry Division, the Queensland Agricultural College, and the University of NSW; and on food additives at Bush Boake Allen Australia Ltd, and Mauri Brothers and Thompson Research Laboratories Flavours and Additives Company.

FOOD ENGINEERING

28.5.39 This area in food R&D covers programs in food engineering that have application across a number of commodity groups. There are several such projects at FRL, concerned with flame sterilisation of canned foods, the use of ozone as a sterilant in food processing, and studies in heat transfer and air circulation in connection with the transport and storage of foods (staff: 7 total, 4 professional; budget: \$184,000). Improvements in handling and road transport of fruits and vegetables are the object of a program at the Sandy Trout Food Preservation Research Laboratory (staff: 3 total, 2 professional; budget: \$61,000).

28.5.40 Techniques of drying, including solar drying, are being studied at the Universities of Tasmania and NSW. At Commonwealth Industrial Gases (CIG) Ltd a development program is well-advanced on the use of liquid carbon dioxide as an aerosol propellant for insecticides and deodorants in food factories, and on a new system for dispensing liquid foods by the use of a pressure of nitrogen and nitrous oxide (staff: 3 professional).

FOOD PACKAGING

28.5.41 Investigations on performance and engineering aspects of metal containers for canned and frozen foods are in progress at FRL, the Sandy Trout Food Preservation Laboratory, J. Gadsden Pty Ltd and Australian Iron and Steel Pty Ltd (staff: 9 total, 4 professional). FRL also supports a program on flexible film packages for foods, concerned with improved barrier properties against transfer of gases (staff: 3 total, 2 professional; budget: \$92,000). Major programs on food packaging technology are undertaken by Kraft Foods Ltd (staff: 8 total, 5 professional), Wrightcel Ltd (staff: 7 total, 5 professional), and Containers Ltd. The Queensland Department of Primary Industries, Horticultural Research Station is developing improved packages for fresh fruit and vegetables. Considerable R&D is also carried out by paper-board manufacturers and converters in developing better packages for many purposes, e.g., fresh fruit containers resistant to cold storage.

PRODUCT DEVELOPMENT

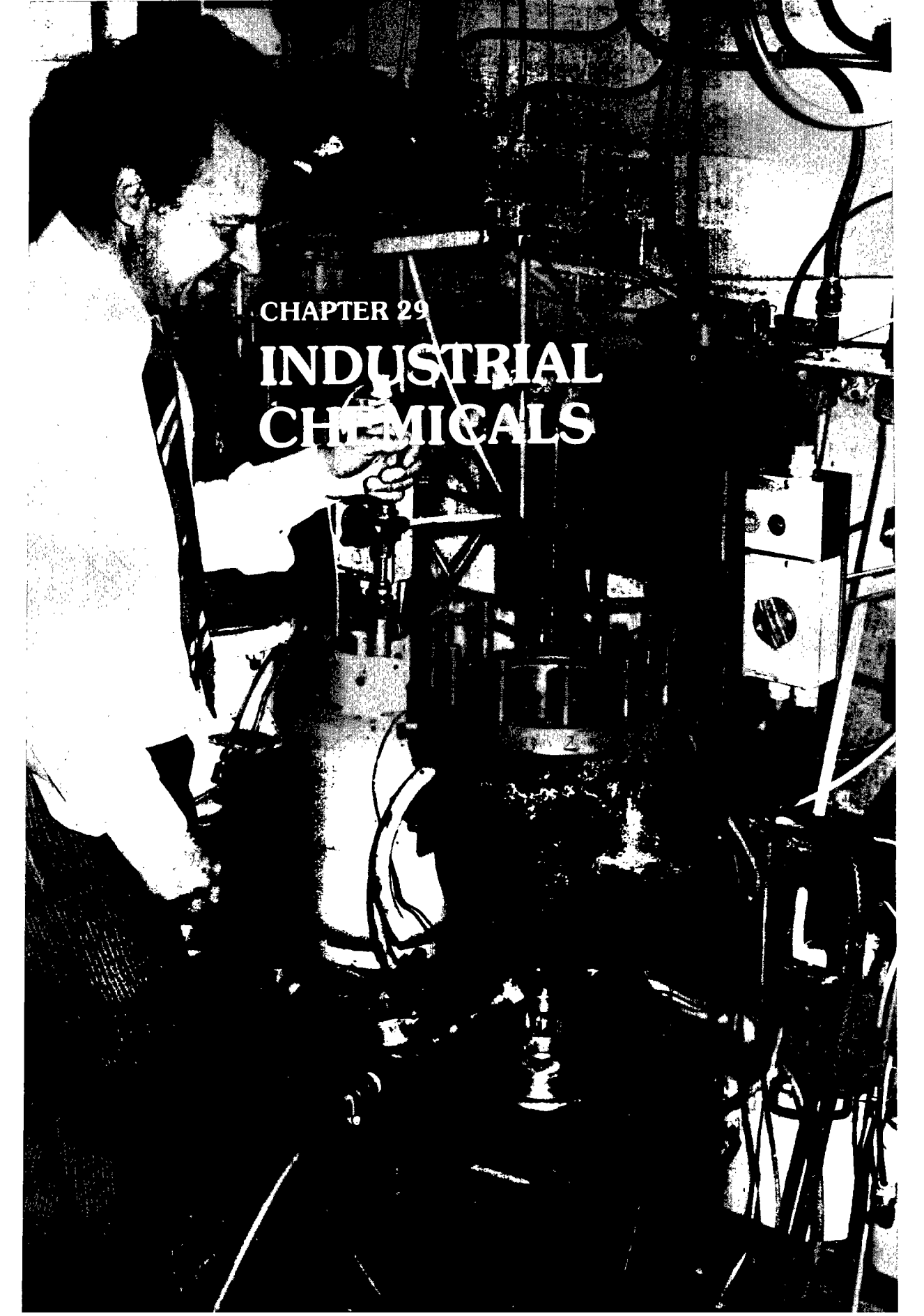
28.5.42 Food R&D in many companies in the food industry is confined to product, process and package development in connection with their specific lines of production and their marketing strategies. Some such activities have been mentioned under the commodity groups. In addition there are several companies with broader interests: H.J. Heinz Co. Australia Ltd. on canned and dried foods including baby foods (staff: 18 total, 11 professional); Rosella Foods Pty Ltd on dried and canned convenience foods (staff: 5 professional); Master Foods of Australia Pty Ltd on fruit, vegetable, meat, and seafoods products (staff: 9 total, 4 professional); Mauri Brothers and Thompson Research Laboratories on fruit juice and

dessert products (staff: 7 total, 5 professional). Other organisations which are involved are Kraft Foods Ltd; Cerebos (Australia) Ltd; Colman Foods; Amatil Ltd; Kitchens of Sara Lee (Australia) Pty Ltd; and A.W. Allen Ltd.

28.5.43 The development, processing and packaging of special ration packs for the Defence Services, and determination of their nutritive value and acceptability is the responsibility of the Armed Forces Food Science Establishment (staff: 34 total, 10 professional; budget: \$400,000).

UTILISATION OF WASTES AND CONTROL OF POLLUTION

28.5.44 This area, of much topical concern to the food industry, has also been partly covered already in the commodity groups: 'Animal Foods', 'Dairy Foods', 'Sugar', and 'Fermented Beverages'. A major program on the purification of waste waters by the use of compressed oxygen to supply biological oxygen demand, and of carbon dioxide to lower pH, which has been undertaken by CIG Ltd is expected to require a staff of 20 in 1977-78. FRL is developing methods for conversion of solid food wastes into methane, the South Australian Institute of Technology is working on winery wastes, and Bush Boake Allen Australia Ltd on control of odour pollution. Long term, bulk storage of single-strength whey for pig feeding has been developed by Kraft Foods Ltd, together with successful procedures for spray irrigation of pastures with whey.



CHAPTER 29

INDUSTRIAL CHEMICALS

Photograph: New techniques for manufacturing polyvinyl chloride (PVC) being developed in ICI Australia's Central Research Laboratories at Ascot Vale in Victoria. These processes are being incorporated into the company's \$36million PVC plant under construction at Laverton, Victoria. (Photograph courtesy ICI Australia Ltd).

CHAPTER 29

INDUSTRIAL CHEMICALS

29.1 DEFINITION OF AREA COVERED

HISTORY AND CURRENT SIZE

29.1.1 The chemical industry, a minor industry in Australia prior to World War II, underwent major development between 1940 and 1965 under the Government's post-war reconstruction program. Growth was encouraged by protective tariffs, together with investment and export incentives. By 1960 it constituted a well-developed industry manufacturing the bulk of products used in Australia. Today, Australia manufactures virtually all those products which are economically viable in the small Australian market. Table 29.1 shows estimates of several parameters of the industry in 1977.

TABLE 29.1

AUSTRALIAN INDUSTRIAL CHEMICALS INDUSTRY (1977)

	Funds Employed (\$million)	Annual Sales (\$million)	Employees ('000)	No. of Plants
Chemicals & Plastics	1000	1150	12	190
Artificial fertilisers				
Industrial gases				
Agricultural chemicals	380	970	16	180
Paint Industries	—	—	—	—
TOTAL	1380	2120	28	370

29.1.2 The industry is highly capital intensive with funds employed of the order of \$80,000 per employee in the large chemicals and plastics sector. Products from the industry flow to a wide range of downstream industries. Around 95% of output is sold locally, and 5% exported.

STRUCTURE

29.1.3 In very broad terms the major raw materials are oil and gas, common salt, phosphate rock, and sulphur (in Australia largely derived from sulphide ores). From these stem dozens of intermediates and

hundreds of end-products. Operations from basic raw material to finished product tend to proceed through recognisable steps, each with a different level of capital required. The progression from cracking stock through to polystyrene is shown as an example in Table 29.2.

TABLE 29.2

POLYSTYRENE PRODUCTION

	Petro-chemical Cracker	Chemical Intermediate Plant	Polymer Plant	Plastics Converters
Product	Ethylene Benzene	Styrene Monomer	Poly- styrene	Plastic Sheet Moulded articles
Minimum plant capital(\$million)	250	40	5	0.25
No. of plants in Australia	2	2	2	Hundreds

29.1.4 A broadly similar picture applies to the progression from the other basic raw materials through to finished products with capital requirement per plant declining progressively as the process approaches the consumer level.

ROLE OF OVERSEAS COMPANIES

29.1.5 In terms of funds employed and of the origin of its technology the heavy end of the process chain described above tends to be occupied by Australian subsidiaries of overseas companies, some of which have substantial Australian shareholdings. Australian companies are bunched at the low capital end. Virtually all the major, world, chemical companies have subsidiaries in Australia.

29.1.6 There appear to be two main reasons for this.

Historically the technologies were developed overseas. In the main period of Australia's industrialisation, up to the 1960's, the technologies were closely guarded by their overseas originators, as proprietary technology. In consequence, companies with particular product expertise have built, and have retained, very strong market positions.

The minimum capital for the erection of a plant is often beyond local resources.

29.1.7 Generally, each major, world, chemical company has a limited product portfolio in which it specialises, and the Australian subsidiaries follow the parental pattern. As a result there are usually between one and three producers of the industry's major materials. For example:

<u>Product</u>	<u>Producers</u>
Ethylene	Altona Petrochemicals Co Ltd ICI Australia Ltd Shell Chemicals (Australia) Pty Ltd
Phenol	Monsanto Australia Ltd
Phosphates	Albright and Wilson (Australia) Ltd
Polyvinyl Chloride	ICI Australia Ltd B.F. Goodrich Chemical Ltd
Polyethylene	ICI Australia Ltd Hoechst Australia Ltd Union Carbide Australia Ltd
Styrene Monomer	Dow Chemical (Australia) Ltd Hydro Carbon Products Pty Ltd (BHP/Monsanto)
Formaldehyde	ICI Australia Ltd Borden Chemical Co (Aust) Pty Ltd

HIGH QUALIFICATIONS OF EMPLOYEES

29.1.8 In addition to being capital intensive, the industry has a high technology level, and employs tertiary-qualified personnel at around two and a half times the level of general industry. In 1973 (latest available figures), tertiary-qualified personnel constituted some 20% of employment in the industry. For comparison, in 1966 the figure was 19%, at which time the all-industry ratio was 7% (latest figure available). These people are employed as analysts, development and research chemists, chemical engineers, plant supervisors, technical salesmen, development specialists, engineers and managers, etc. The industry is also a major customer of the construction industry for the building of high-technology plant.

SCALE DISADVANTAGE

29.1.9 The limited domestic market and its geographic spread puts the industry in Australia at a considerable scale, and hence cost, disadvantage against major world producers in the USA, the EEC and Japan. At the heavy capital end, it is common to find Australian plants of one-third to one-fifth the capacity of the world's largest. The scale disadvantage is

aggravated by our higher construction costs. As a result, unit product costs are increased through higher costs of capital, labour, energy, maintenance, selling and administration. Export markets have been so notoriously unstable, both as to price and security of volume, that, with a relatively small base load from the domestic market, the concept of building world scale plants in Australia involves risks no one has yet been prepared to take.

29.1.10 In the 1960's it was hoped that these scale disadvantages would gradually decrease to a stable level; in some areas this is occurring, e.g. with PVC (polyvinylchloride) plants, but the process is slower than was originally predicted. Appendix 29.1, based on current, cost data of a large Australia-based engineering department, demonstrates the effect of scale and higher construction costs on cost per year-tonne.

29.1.11 In spite of the scale disadvantages of the chemical industry, its tariff protection is moderate: with an average of 26% it is below that of the manufacturing sector as a whole (28%) and it is in line with that of other industrial nations with larger markets and/or lower labour costs. Appendix 29.2 shows comparative tariff data for plastics.

29.1.12 The small market size results in constraints on local research and development. Typically, the world's top chemical companies each spend between \$100million and \$400million annually on R&D; the total Australian industry is estimated to spend about \$20million per annum on R&D. Even if it matched US, R&D expenditure as a percentage of sales (by putting all its funds for innovation into R&D rather than paying for the importation of technology), the total sum available would be no more than \$50-\$60million. This differential puts a severe limitation on the capacity of Australian companies to mount successful invention programs aimed at basic inventions across the board. It is not necessarily expensive to invent something worthwhile at the laboratory bench level, but the development of a viable plant process to prove the invention, and commercialisation, can be extremely expensive (cost ratio R:D from 1:10 to 1:100), and the cost of failure crippling for a small or medium-sized company. This leads to the view that selectivity and concentration on a few strategic areas is vital.

29.1.13 The small market also limits the local capabilities of the chemical plant construction and fabrication industry; the limitation extends to designing for major processes. Design and construction of major plants are handled by local subsidiaries of major, international, construction companies. Speciality equipment such as glass-lined reactors, some pressure vessels and virtually all instruments is supplied from overseas. Some highly corrosion-resistant metals are not made in Australia.

SOURCES OF TECHNOLOGY

29.1.14 The bulk of technology used by the Australian chemical industry is derived from the world's major chemical companies. Two of the major exceptions to this are the technology for the manufacture of

superphosphate where local developments have been dominant and in the technology for some 'effect-chemicals'. 'Effect-chemicals' are those whose value is determined by their effect rather than their raw material cost, e.g. drugs, surface-active agents, many agricultural chemicals and biocides. The discovery of 'effect-chemicals' is usually expensive as there is a high research component in the costs.

29.1.15 In most cases the technology is captively transferred from parent to local subsidiary, although some is obtained at arm's length from unrelated companies, and some is patent-free and has been developed or redeveloped locally. The captive transfer seems to operate particularly efficiently, and in most instances is still the most economic route to adaptation. Frequently a fee is paid either by way of a running royalty on sales, by down payment, or by a management service fee. An estimate puts the annual outflow from such transfer at about \$15million. Most big Australian companies are well satisfied with value obtained from these payments, particularly at the high-capital end of the industry.

29.1.16 The royalty payments, both from and to Australia, may not reflect clearly the value of the flow of technology. Some subsidiaries receive technology free of charge; repayment of R&D cost is then inextricably interwoven with the reward of capital in profit; i.e. it becomes a part (probably relatively small) of reinvestment and dividend payment. In reverse, some Australian R&D contributions flow overseas free of charge, usually in return for the vastly greater flow in the reverse direction. It is difficult to assess the role which technology has played in the accumulated equity built up by overseas companies in their Australian subsidiaries but it must have been a very important factor.

29.1.17 Australia is kept well abreast of the latest world development in all major segments of the industry by this constant technology input from world leaders, generally from parent to subsidiary. This is achieved both by transmission of written information and by visits of personnel in both directions. The end-result is highly specialised and up-to-date knowledge of the world industry spread across a large number of companies on the Australian scene. For example, ICI and Goodrich are kept up-to-date on the production of polyvinylchloride, Albright and Wilson on phosphates, Monsanto on phenol.

AUSTRALIAN R&D - ADAPTATION

29.1.18 By far the bulk of Australia's industrial R&D effort lies in adaptation and extension of world-based, demonstrated technology. The adaptation can be by a product or a process or the introduction of a product into additional fields. There is some invention and subsequent commercialisation in Australia but it is generally confined to the largest companies in the industry, and it is usually in areas where the local market is relatively large, e.g. agricultural chemicals or paints. Some of this locally developed technology has been licensed overseas, but only one company is earning royalties in excess of \$1million per annum (and this is no more than one-quarter of its R&D expenditure).

29.1.19 This adaptive role has developed as a result of the small scale of the Australian market (since initially, all local research is aimed at that market). Because of market scale, research on say petrochemical intermediates can only be contemplated in co-ordination with overseas associates as part of a broader program of information exchange. In isolation the high cost of research and particularly of development, cannot be rewarded from the Australian market alone. There are a few examples of such co-ordinated research, e.g. the oxychlorination route to vinylchloride or PVC polymerisation.

29.1.20 The Australian chemical industry requires highly developed, adaptive skills in order to modify processes to suit local conditions and to modify products to meet local market requirements. This capability for adaptation requires skills of a high order, involving fundamental knowledge of bench, and complex process chemistry and chemical engineering, and a highly developed capability for commercialisation.

29.2 R&D ACTIVITIES

SCOPE AND EXPENDITURE

29.2.1 The industry's R&D may be classified as follows:

• Fundamental research

• Product or Process R&D	category 1	adaptation and improvement, including cost reduction
	category 2	extension to new technologies or markets
	category 3	invention of new products or processes

R&D, particularly product and process research, embraces the following elements:

- economic evaluation;
- process development;
- pilot plant design, construction and operation;
- market development and technical service;
- productivity improvement programs.

29.2.2 Current expenditure on R&D in the industry is about \$20 million per annum. This represents about 1% of annual sales. The chemicals and

plastics segment runs somewhat higher at about 1.5% of net sales. Generally speaking, the larger the company the greater the expenditure on R&D relative to sales. It is estimated that no company spends more than 2.5% of annual sales revenue on R&D. Some of the small ones spend very little.

29.2.3 Industry R&D is very heavily related to market needs and cost-reduction programs, with pollution abatement taking an increasing proportion. Very approximately, 80-85% of R&D monies are spent on product and process adaptation and improvement (category 1 - see 29.2.1), 10-15% on extending applications of existing products or processes (category 2), and perhaps 3-5% on fundamental, new product and new process research (category 3). There is somewhat greater emphasis on categories 2 and 3 in the larger companies, particularly in their research departments.

COMPARISON WITH USA LEVELS

29.2.4 For comparison purposes Table 29.3 shows the scale of expenditure on R&D by the chemical industries in Australia and in the USA. Both the US and the EEC spend a much higher proportion of their monies on fundamental research and product or process invention.

TABLE 29.3

INDUSTRIAL CHEMICALS IN USA AND AUSTRALIA

	USA(1976) (US\$million)	Australia(1977) (\$Amillion)
Total sales	56,000	2,100
R&D expenditure	1,440	20
R&D as % of sales	2.6	1.0

29.2.5 Du Pont heads the USA list with expenditure of \$353million representing 4.2% of sales. Four companies, Du Pont, Dow, Union Carbide and Monsanto all spent in excess of \$100million on R&D in 1976, but many others operate internationally with much smaller R&D budgets.

29.2.6 If we add the annual payment of \$A15million for royalties etc. to the cost of local R&D, \$A20million, the resulting \$A35million per annum for the cost of technology represents only 1.7% of the sales by the industry. This is still well below the figure for the USA.

INFRASTRUCTURE OF R&D IN INDUSTRY

29.2.7 In the Australian chemical industry R&D is carried out:

- (a) in separate research establishments answering to a Research Director or Research Manager. The 12 largest establishments are, by total number of employees (graduates and assistants, 1975):

ICI Australia Ltd	218
CSR Ltd (a)	181 (part in minerals research)
Dulux	140 (of this, 100 in product development)
Kodak (a)	80
Dunlop	58 (recently closed down)
Monsanto	45
Taubman	42
Humes (a)	26
Olympic (a)	25
Australian Gypsum	23
Shell	22
Roche	28

Note: The companies marked (a) are classifiable as chemical industry in part only.

The Broken Hill Proprietary Co Ltd (340), Australian Paper Manufacturers Ltd (80), Australian Consolidated Industries Ltd (190), Comalco (25), MIM Holdings Ltd (180) and many others carry out some chemical R&D projects within the total framework of their industries. Programs are usually 'sponsored', that is agreed and paid for by operational units (sales or production); some companies pay for selected larger (or even all) programs corporately. Objectives (topics) emanate from the R&D departments, operating units (sales, production), and a few are stimulated by Government organisations (CSIRO, Departments). Most projects, whether initiated by R&D or by operating units, are market-oriented and fall within the framework of existing business.

- (b) in factory development teams. Most of this work relates to process adaptation, capacity extensions or efficiency improvement (cost reduction) and is sponsored or directed by Works or Development Managers.
- (c) in market development and technical service teams. Products usually involve short-term problem-solving for customers to promote new products or uses. This work is of considerable economic importance in the transference of technology to industries that are less developed technically.

EXAMPLES

29.2.28 The examples below are not necessarily current activities. They do, however, illustrate the sort of work which has been done over the past decade and which is at present being done. They are classified broadly under five main headings: Invention of Products, Invention of Processes, Modification of Products, Modification of Processes, Developments and New Applications.

Invention of products

- . One company has invented a chemical for the control of tick infestation in cattle. This is the first, and only biologically active, chemical wholly discovered and developed in Australia. After toxicology testing in the UK the company designed and built pilot and manufacturing plants and commercialised the product.
- . Mining chemicals, particularly flotation chemicals, were invented in Australia and have been highly profitable commercially. They are used in Australia and exported to many countries; the processes are licensed.
- . The flame ionisation detector, an extremely sensitive, analytical instrument was discovered by a chemical company. In conjunction with chromatographs, this instrument is the most widely used tool in pollution control throughout the world. It has been licensed to some 30 companies and has earned \$0.7million in royalties.
- . Chemicals to promote the ripening of sugar cane were successfully investigated and developed for use in countries whose natural ripening conditions are not as favourable as in Australia.
- . A paint company developed anti-fouling paints for the Royal Australian Navy since none available was suitable. Australia's warm coastal waters make fouling a serious problem. This invention is beginning to be applied commercially to small boats and ships.
- . A paint manufacturer developed a paint opacifier which uses the masking properties of porous plastic beads in place of titanium filler. The product and process are now being licensed in the UK and USA.
- . A wool-washing detergent was developed, in conjunction with CSIRO, which allows boiling of woollen materials, e.g. blankets.

Invention of processes

A process was invented for the synthesis of an anthelmintic drug (for killing parasitic worms in sheep) and subsequently the process was extended to the resolution of the compound (tetramisole) into its optical isomers. This has been an outstanding commercial success, both in Australia and overseas (worldwide sales \$50million per annum, royalties earned in the USA, South America and the UK exceed \$6million).

An Australian company discovered, or more correctly, re-discovered the oxychlorination process using waste hydrogen chloride for the manufacture of vinylchloride (VCM) and built the first plant outside USA. The relatively small, but full-scale, Australian plant was in effect a petrochemical, pilot plant for later, larger UK plants.

A process for the separation by extraction of sorbitol and mannitol from sucrose was evolved with some assistance from the University of Queensland.

A company, in conjunction with its UK and Canadian associates and an American company, has developed a new, safer generation of explosives replacing nitroglycerine. This technology is now the basis of virtually all explosives used for mining in Australia, and of the Australian explosives industry.

A process was investigated and developed to produce isopropyl percarbonate which is used in the manufacture of plastic lenses.

A company, in conjunction with the CSIRO, developed novel, thermally regenerable, ion-exchange resins and a process for the desalination of brackish water. The company has erected plant for resin production, has built a full-scale water treatment plant and has formed joint companies overseas to market the process.

Two companies assisted to commercialise the CSIRO invention of the use of a modified cellulose acetate to absorb limonin, which causes a bitter taste, from the juice of navel oranges.

A process was developed and a pilot plant built for the production of dextrinase which is used to remove the dextrin that can build up to objectionable levels in sugar mills when overripe cane is being crushed.

On the basis of an Australian university publication, which described a new reaction, a company invented a continuous process for producing the principal intermediate to one of the world's most widely used herbicides ('DIQUAT'). The small market made manufacture uneconomical and a license was therefore granted overseas, where the process is commercial.

- . A novel process for continuous production of thermosetting moulding compounds was evolved which replaced the previous batch process.
- . The Brodie purifier was invented and developed to separate para- and ortho-dichlorobenzene. The process is based on continuous crystallisation from the melt and is applicable to other processes of purification by crystallisation; it is now licensed in three overseas countries.
- . A process was developed for bacterial oxidation of the effluent from a plant that was manufacturing titanium oxide.
- . A new type of gas regulator for welding was invented; special gas mixtures for welding, deodorising and for the use of carbon dioxide as a propellant were developed.
- . Australia has always been in the forefront with processes associated with the production of superphosphate.

Modification of products

- . Sulphur-fortified superphosphate was developed for use on sulphur deficient soils in NSW.
- . Phenolic moulding powder formulations suitable for injection moulding were developed; these reduce costs and improve quality compared with the old compression moulding techniques.
- . A series of chemicals based on ethylene oxide (brake fluids, frothers and detergents) was developed. Although many of these chemicals were not new, the route of local development, in preference to licensing, was chosen. These derivatives support a whole sector of the petrochemical industry and, incidentally, the Australian company developed the downstream industry before a parallel development occurred in the UK.
- . Overseas technology was modified to produce a biodegradable, detergent alkylate suitable for the Australian market.
- . A highly washable, decorative, wall paint, not damaged by scrubbing, was developed and commercialised.
- . There are endless examples of minor product modifications which are at the heart of the continuity of this industry. However, most are too small to warrant reporting separately.

Modification of processes

- . A process for recovery of fluorosilicic acid from fertiliser production was modified to achieve uniform recovery rates.

- . A membrane type, caustic-chlorine cell was designed and built for small scale operation in Australia.
- . Overseas technology for the manufacture of detergent phosphate was scaled down to attain economic viability in Australia. The process has been licensed overseas.
- . A very compact, low-capital plant for burning phosphorus to produce phosphoric acid was invented and developed in Australia.
- . The process for production of hydrogen peroxide was simplified to reduce capital cost and make possible an economic plant in Australia.

Again, there are endless smaller examples. A large number result from continuing cost-reduction programs which are essential for viability of the industry.

Developments and new applications

Some of the more important new applications and developments are:

- . the use of liquid nitrogen for food processing and preservation;
- . the use of oxygen in sewage and waste water treatment;
- . the extension, to apple and pear orchards, of the use of a phosphorus containing insecticide, which had been developed overseas;
- . high concentration liquid detergents to minimise cost of transporting water; and
- . the application of hydrogen peroxide in metal processing.

APPENDIX 29.1

COMPARISON OF ETHYLENE COSTS IN AUSTRALIA AND UNITED KINGDOM

The attached graph provides a comparison of ethylene costs in Australia and United Kingdom for plant sizes in the range 50,000 - 500,000 tpa (tonnes per annum).

The calculations are based on current construction and operating costs (1977 \$A) assuming:

- . 15 year plant life
- . operation of the plant at full output
- . 25% return (before tax) on capital

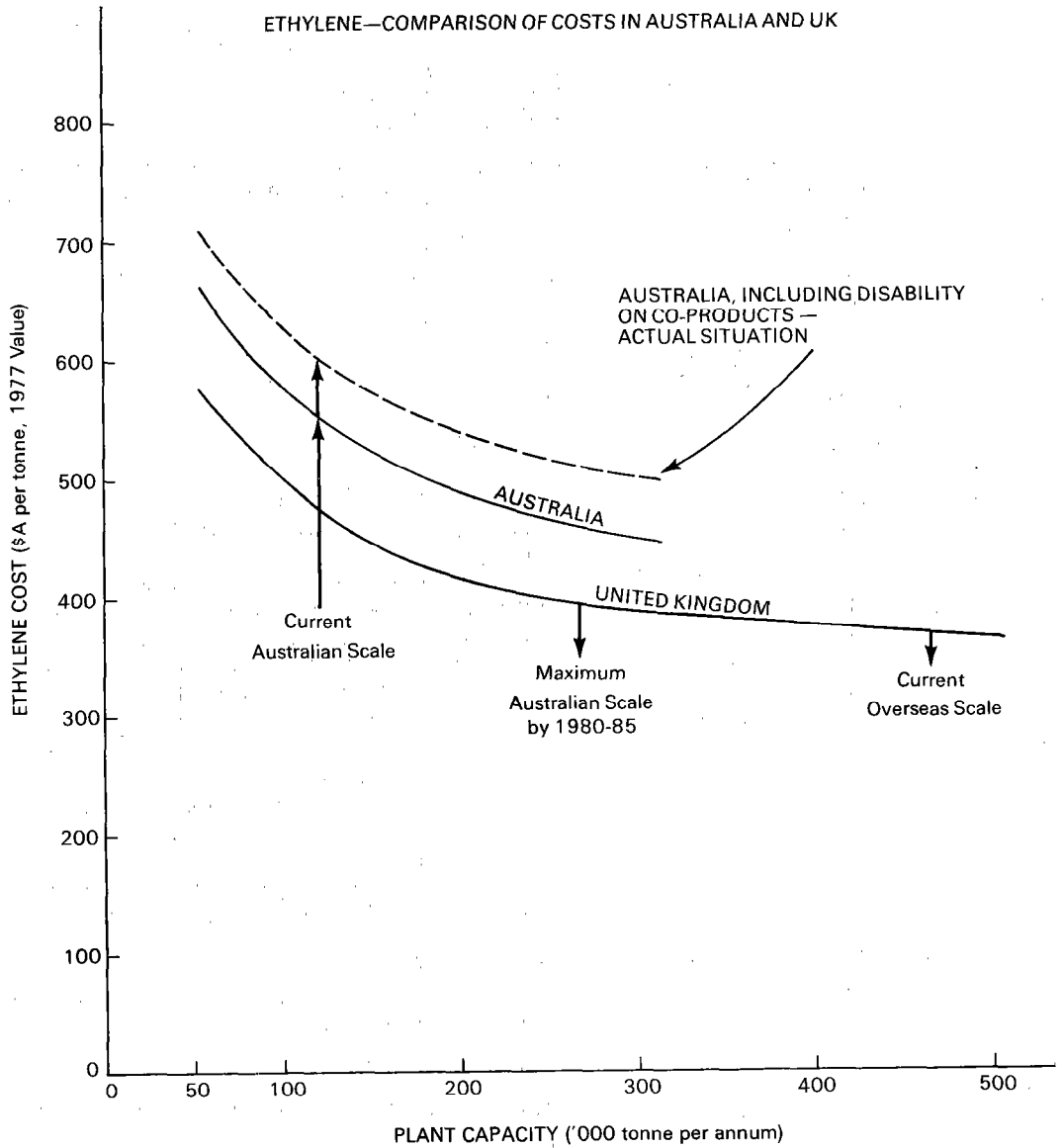
The higher cost of ethylene in Australia reflects the higher costs of labour and of plant construction compared with those in the United Kingdom.

Feedstock prices are assumed to be at world parity for both Australia and the United Kingdom. Chemical markets in Australia for co-products, particularly gasoline and propylene, are not developed to the same degree as in major overseas countries including United Kingdom and hence average prices for these in Australia tend to be lower. The extent of the disability on co-products is shown as the dotted line on the attached graph.

Future investment in ethylene manufacture in Australia will depend on a satisfactory balance being achieved between adverse and favourable factors as indicated below:

adverse factors	-	scale (maximum 300,000 tpa in Australia compared with 500,000 tpa overseas)
	-	high Australian costs
favourable factors	-	raw materials (locally produced feedstocks slightly cheaper)
	-	tariff on derivatives
	-	freight from overseas countries

ETHYLENE—COMPARISON OF COSTS IN AUSTRALIA AND UK



APPENDIX 29.2

COMPARATIVE TARIFF RATES - POLYOLEFINES

Product	Tariff	IMPORTING COUNTRY							
		EEC	Spain	Sth Africa	Japan	Sth Korea	Taiwan	USA	Australia
PP	BASE:	c.i.f.	c.i.f.	f.o.b.	-	c.i.f.(5)	Wholesale market value: c.i.f.(5)	f.o.b.	f.o.b.
	RATE:	18.4%	20.5%	20%	¥28/kg	30-50% (Grades Vary)	33% + Quantitative Restrictions	10% ad val. + 1.3c/lb	22.5%
	Exporting country f.o.b. equiv.	USA 22.5%	EEC ca22%	EEC 20%	USA >10%	Japan 33-53%	Japan Equiv 100% Admin Protn	EEC >14%	Japan >22.5%
	Duty as % of Local SP (1)	15.5%	16.6%	13.8%	12.2%	23-35%	33%	12.1%	16.1%
LDPE	BASE:	c.i.f.	c.i.f.	f.o.b.	-	c.i.f.	Wholesale Mkt Value: (c.i.f. +)	f.o.b.	f.o.b.
	RATE:	16%	20.5%	20%	¥32/kg	30%	33% + Quantitative Restrictions	10% ad val. + 1.3c/lb	30% MFN 22.5%Pref
	Exporting country f.o.b. equiv.	Spain 18% Jap >20%	EEC >21%	EEC 20%	Korea >18%	Japan 33%	Japan Equiv 100% Admin Protn	EEC >15%	Japan as above
	Exporting country f.o.b. equiv.	USA/Jap	EEC	EEC	USA	Japan		EEC	Japan
	Duty as % of Local SP (1)	13.8%	15.4%	13.2%	14.5%	23.2%	33%	12.3%	20.3%

PVC	BASE:	c.i.f.	c.i.f. (4)	f.o.b. (2)	c.i.f.	N.A.	Quantitative Restrictions	c.i.f.	f.o.b.
	RATE:	16% (3)	28%	20% & Import Licence	8%			10% ad val. + 1.3 c/lb	30% MFN 22.5% Pref
	Exporting country	USA	USA	EEC	Taiwan			EEC	Japan
	f.o.b. equiv.	18%	31%	20%	9%			18%	30%
	Duty as a % of Local SP	13.5%	22%	14%	7%			15%	19%

Abbreviations PP = polypropylene; LDPE = low-density polyethylene; PVC = polyvinylchloride; f.o.b. = free on board; c.i.f. = cost insurance freight; MFN = most favoured nation tariff; pref. = preferential tariff; ad val. = on the value; SP = selling price.

- Notes:
1. based on current freight rates and selling prices
Duty paid c.i.f. is lower than selling prices of locally produced products in most cases
f.o.b's are generally below local SP's in exporting countries but dumping action usually is not taken; SP's in importing country match market opportunities in relation to time and Polymer grades so that apparent anomalies in pricing appear:
e.g. Spain: 1% of LDPE imports come in at twice the price of local products; 10% of LDPE sales are imported mostly from EEC yet Spain occasionally exports surplus grades.
 2. Import licences are required as PVC is on the list of restricted imports in South Africa. The 20% therefore does not have much meaning in terms of protection.
 3. This rate applies from 1 July 1977 when previous minor differences in rates were removed. Imports are duty free from EFTA and developing countries; duties do not apply to goods moving between EEC countries.
 4. The Spanish rate for most favoured nation countries and also the UK is 28%. For the EEC six it is 21%.
 5. Korea and Taiwan as 'developing countries' enjoy a tariff advantage of 10% for PP over other countries importing into Australia; yet their petrochemical plants, mostly foreign owned, enjoy many cost advantages over products from Australian plants.

Source: 'The Manufacturing of Industrial Chemicals & Synthetic Resins in Australia', July 1977. Paper by the Australian Chemical Industry Council (ACIC).

CHAPTER 30

**METAL PRODUCTS
AND MACHINERY**

Photograph: Experimental pressing on a 500 tonne press to determine formability of an experimental high-strength formable steel.
(Photograph courtesy The Broken Hill Proprietary Company Ltd).

CHAPTER 30

METAL PRODUCTS AND MACHINERY

30.1 INTRODUCTION

30.1.1 This Chapter provides a descriptive background to R&D carried out in, and for, the metal products and machinery industries. The metal products and machinery area encompasses a very large and diverse group of organisations (particularly in the industrial sector) and, for this reason, information currently available to ASTEC is far from comprehensive and does not allow quantified comments to be made on the extent or quality of the relevant R&D. The material which follows therefore only gives a broad outline of the area, with a brief description of some of the main R&D establishments and the R&D programs being undertaken by them.

30.1.2 The Chapter covers R&D infra-structure and activities in basic metal products, fabricated metal products, transport equipment and other machinery and equipment. These areas include a diverse range of activities which comprise approximately 35% of the establishments and 42% of the manpower in the whole manufacturing industry sector. The turnover from these areas is some 40% of the total manufacturing industry turnover. Table 30.1 summarises some of this information.

TABLE 30.1

MANUFACTURING ESTABLISHMENTS, EMPLOYMENT AND TURNOVER(a)

<u>Industry Division or Sub-Division</u>	<u>ASIC Code(b)</u>	<u>No. of Establishments</u>	<u>Employment (^{'000})</u>	<u>Turnover (\$million)</u>
Basic metal products	29	550	94	4,668
Fabricated metal products	31	3,932	105	2,864
Transport Equipment	32	1,302	142	4,100
Other Machinery and Equipment	33	3,812	179	4,747
Total		9,596	520	16,379
Total in all manufacturing Industry		<u>27,523</u>	<u>1,201</u>	<u>39,473</u>

(a) These figures cover only those establishments employing four or more persons. There are about 3,700 additional metal products and machinery establishments, employing less than four persons each which together employ an additional 7,400 persons.

(b) Australian Standard Industrial Classification as used by the industry and by the Australian Bureau of Statistics [1].

Source: Australian Bureau of Statistics, Manufacturing Establishments - Summary of Operations by Industry Class. Australia 1975-76, Cat.No. 8201.0.

30.2 ORGANISATION AND POLICIES

GENERAL MANUFACTURING INDUSTRY

30.2.1 Employment and general activity in manufacturing industry depend on the interaction of a number of complex factors. In the 1950's there was a relative boom in manufacturing industry in Australia, supported by a broad policy of import replacement through tariff protection which had the result that, between 1950 and 1960, the proportion of Gross Domestic Product (GDP) contributed by manufacturing industry rose from 24% to 30%. Since then, manufacturing has declined in relative importance to around 24% of GDP, employing around 22% of the total workforce.

30.2.2 Australia participates in multilateral negotiations under the General Agreement on Tariffs and Trade (GATT). Present GATT negotiations are aimed at realising the benefits of a higher level of international specialisation. To assist in these negotiations, and as a response to the Government White Paper on Manufacturing Industry [2], the Department of Productivity recently prepared Working Papers [3,4] which present policy options which the Government could use to encourage industrial development, based on specialisation, modernisation and new approaches to management and labour. Some actions, including initiatives through the Industry Technology Advancement Program, which are particularly relevant to R&D in the metal industries, have followed these working papers. A lack of specialisation has contributed, at least in part, to the country's inability to update manufacturing plant, and at present, Australian manufacturing industry is reported to have only 25% of its plant that is less than 10 years old; the comparable figure in Japan is 65%.

30.2.3 In regard to technology in Australian manufacturing industry, the ability of at least the larger establishments in Australian industry to assimilate, and to adapt, foreign technology quickly is indicated by a number of surveys and studies and by the experience of State and Commonwealth agencies over recent years. The factors that most limit technological innovation are to be found in the environment which shapes profit-based incentives for innovation. These factors include Australia's small domestic market, its geographic isolation from its principal trading partners, its high standard (cost) of living and, to some extent, the purchasing policies of Australian governments. In addition, some demarcation and associated industrial relations problems are experienced due to the large number of trade unions and their overlapping constitutions.

THE AUSTRALIAN METAL INDUSTRIES

30.2.4 This area, like manufacturing industry generally, includes a large number of small establishments. In 1974-75 [5], some 60% of establishments employed less than 10 people while only 7% employed more than 100 people.

30.2.5 Evidence suggesting that the majority of Australian companies are little involved with development work can be found in the relatively low number of patent applications made in Australia as compared, on a per capita basis, with other developed countries [4]. National expenditure on R&D is substantially funded by the government, and the majority of government funding is directed to academic institutions and to government laboratories.

OVERSEAS CONTROL

30.2.6 Over the period 1966-67 to 1972-73, foreign ownership of manufacturing industry, measured by value of production, increased from 25% to 31% and foreign control from 29% to 34%. Of the 200 largest enterprises in 1972-73, 87, accounting for 44% of production, were classified as foreign controlled, while in 1975-76, 86 of the 200 largest enterprises, accounting for 43% of production, were classified as foreign controlled [6]. These figures suggest that foreign control tends to be concentrated in a relatively small number of large organisations. The extent of foreign control varies from industry to industry, with a tendency to be more significant in capital-intensive and high-technology industries.

30.3 ORGANISATION OF R&D

GENERAL

30.3.1 Government assistance to industrial R&D in the past has been limited to the mechanisms of the Australian Industrial Research and Development Incentives Board (AIRDIB). Assistance to manufacturing industry totalled \$19.3million to 1390 companies in 1975-76. Of this, \$5.8million was provided to companies in the 'Metal manufacturing' and 'Machinery' industry classes. More information on the operations of AIRDIB is provided in Chapter 6 (Volume 1A).

INDUSTRIAL RESEARCH ASSOCIATIONS

30.3.2 Research associations are usually formed by the co-operative efforts of companies wishing to have research performed in their particular industry. They promote the interests of particular sub-divisions of manufacturing industry. There are 14 research associations recognised for income tax purposes. Of the five supported by the Commonwealth Government, through CSIRO, only the Australian Welding Research Association (AWRA) is primarily concerned with the metal products industries, but there are others whose activities are relevant to this chapter.

Australian Welding Research Association (AWRA)

30.3.3 AWRA was incorporated as a non-profit company in 1964. It received substantial help from industry and CSIRO then sponsored the Association for some time. A Commonwealth subsidy on a dollar for dollar basis was arranged later. AWRA undertakes some research itself as well as arranging for co-operative work to be done for member companies. It also provides support, at a modest level, for selected research projects. AWRA also provides technical services, and collates and disseminates information from overseas on welding research, design, fabrication and inspection.

Australian Mineral Industries Research Association (AMIRA)

30.3.4 AMIRA is an association of a wide range of private enterprise companies in the mining and mineral processing fields. The Association does not perform its own R&D but places contracts with CSIRO, Amdel (see 30.3.6), the Australian Atomic Energy Commission (AAEC), tertiary education institutions and industry. Each project is separately financed by grants from groups of member companies having a common interest in the particular project. There is no government assistance to AMIRA, costs being met from subscriptions of members and from administrative charges on projects. Since its inception in 1959, the total research expenditure by AMIRA (to June 1976) has amounted to some \$3.2million, with current annual expenditure in the region of \$0.45million. The activities of AMIRA are discussed in more detail in Chapter 24 ('Mining Engineering and Mineral Processing').

Australian Engineering and Building Industries Research Association (AEBIRA)

30.3.5 AEBIRA was formed in Melbourne in 1973. Its organisation was based on that of AMIRA and, like AMIRA, AEBIRA does not perform R&D itself but instead contracts projects to tertiary institutions, CSIRO and private consultants. There is no Commonwealth Government grant to AEBIRA, administrative costs being derived from membership subscriptions. There are at present 41 members of AEBIRA, of which 5 are Commonwealth or State government organisations.

CONTRACT AND SERVICE LABORATORIES

Australian Mineral Development Laboratories (Amdel)

30.3.6 Amdel is a non-profit, contract organisation engaged in development, consulting, and service work for industry and government in the field of mineral and materials science. The organisation is controlled by a council made up of representatives of the minerals industry, the South Australian Government and the Commonwealth Government. The laboratories function on a commercial basis, relying solely on earnings to provide the services offered. The main sources of funds for Amdel are industry (of which nearly 60% comes from members of AMIRA) and government

instrumentalities. Amdel became operative in 1960 with guarantees of funds and work from the South Australian and Commonwealth Governments and from AMIRA. Amdel offers technology with transfer of knowledge and sells a comprehensive interdisciplinary package. On a number of occasions, Amdel has involved other Australian consultants in the project teams, and in submitting proposals for overseas projects, several Australian companies have agreed to supply specialised backup to the Amdel team as required.

OTHER ADVISORY AND LIAISON ORGANISATIONS

Industry Advisory Councils

30.3.7 During 1976, the Minister for Industry and Commerce announced the establishment of a number of Industry Advisory Councils. Their function is to consider issues as they relate to an industry sector, and to provide a means of communication between the Government, manufacturing industry representatives, unions, retailers, consumers and other interested groups. The Councils meet regularly to discuss the current situation in particular industries as well as matters affecting industry viability, employment and development. There are two such Industry Advisory Councils which cover the metal products and machinery industries. These are the Metal Manufacturers Industry Advisory Council and the Heavy Engineering Industry Advisory Council. These two Councils are chaired by the Minister for Industry and Commerce and the Minister for Productivity respectively.

The Australian Innovation Corporation Ltd (AICL)

30.3.8 The Australian Innovation Corporation Ltd (AICL) was established in Melbourne in 1970 by a group of Australian companies and institutions; it is managed on a commercial basis. Although it is rather under-capitalised, AICL provides a range of services to assist the promotion and commercialisation of local research, invention and development; it assists in establishing technology strategies for individual companies and with the acquisition, by licensing, of international technology. The Australian Industrial Development Laboratories operate as a division of AICL and offer the facilities of the R&D laboratories of several companies. AICL has no access of right to discoveries made in government laboratories or in tertiary educational establishments (see 6.4.8, Volume 1A).

MTIA Production Technology Centre

30.3.9 The MTIA (Metal Trades Industry Association) Production Technology Centre was established by the MTIA in association with The Broken Hill Proprietary Company Ltd (BHP). The Centre is situated in the BHP Melbourne Research Laboratories. The MTIA Centre provides advisory and consultancy services to the sheet metal forming industry as well as

undertaking prototype development, failure analysis and other forms of 'trouble-shooting'. A library and information service is also available to interested organisations. The Department of Productivity is monitoring this development as a possible model for other technology centres for manufacturing industry.

Heavy Engineering Manufacturers Association (HEMA)

30.3.10 HEMA was formed in 1968 to foster co-operation between the heavy engineering industry and government in the development of a predominantly Australian-owned manufacturing sector which is based on the utilisation of natural resources. It is a trade association of some 35 individual companies and groups which supply capital plant and equipment in all areas of project development. HEMA is active in promoting an awareness of the national need for research and innovation. It also provides a focal point for industry submissions to government in such matters as finance, export incentives and technical advice.

COMMONWEALTH GOVERNMENT

CSIRO

30.3.11 Several divisions of CSIRO have research programs which are in the area of metal products, and machinery. These include the Divisions of Mechanical Engineering, Materials Science (formerly Tribophysics), Chemical Physics, Forest Research, Radiophysics, the Wool Research Laboratories, the National Measurement Laboratory and the Solar Energy Studies Unit. Much of CSIRO's research is undertaken in collaboration with industry and other research organisations. The CSIRO Patents and Licensing Section in Canberra (Head Office) is also active in facilitating the transfer to industry of CSIRO developments.

30.3.12 The Report of the Independent Inquiry into the CSIRO [7] nominated the problem of interaction between industry and both the CSIRO and institutions for tertiary education as a major one in this area of R&D. The Australian Industrial Research Group (AIRG) is well aware of the problem and of the inefficiencies that result in terms of poor utilisation of indigenous skills. CSIRO, in conjunction with the AIRG, is examining a number of mechanisms to improve the present interfaces between these sectors of activity.

Department of Defence

30.3.13 The Materials Research Laboratories, the Defence Research Centre, Salisbury (formerly the Weapons Research Establishment) and the Aeronautical Research Laboratories all conduct major R&D programs in this area. There is little formal interaction with industry on individual programs.

Department of Productivity

30.3.14 The Commonwealth Department of Productivity develops, and provides advice to the Government on, policies and strategies to stimulate and maintain productivity improvement at the national and industrial levels. It encourages the development of Australian production towards an improved international competitive position and actively supports other Government departments and authorities, and industry-based and associated bodies, in their measures for improving productivity. The Department facilitates the development of Australian industrial potential through encouragement of the allocation of resources to programs of industrial research and development, industrial efficiency, technological innovation, technology transfer, improvement in working conditions, introduction of advanced management practices, and by the provision of assistance in commercial exploitation of Australian inventions. The Department controls the grant of Letters Patent for inventions and the registration of Trade Marks and Designs.

Australian Atomic Energy Commission (AAEC)

30.3.15 The Atomic Energy Research Establishment (AERE) at Lucas Heights is active in R&D in several areas related to metal products, machinery and equipment. AERE has linked effectively with industry on several occasions in specialised areas where complementary expertise has proved to be of mutual benefit to government and industry.

STATE GOVERNMENTS

30.3.16 Most State governments have at least one department which is responsible for industrial assistance, decentralisation, encouragement of innovation, and other associated matters. In some cases, these departments actively foster the establishment of new industries and encourage and assist with the introduction of new technologies into industries. In some cases, they also provide assistance to industry in promoting exports.

TERTIARY EDUCATION INSTITUTIONS

30.3.17 In general there is only limited formal interaction between tertiary institutions and industrial R&D establishments. However, a number of institutions have established independent, commercial companies to promote and manage research and consultancy services to industry, commerce, governments and the community. Examples of this include: Unisearch, a company attached to the University of NSW; Technisearch, at the Royal Melbourne Institute of Technology; SARD in the Swinburne Institute of Technology; WAIT-AID Ltd at the Western Australian Institute of Technology; Techsearch Inc at the South Australian Institute of Technology; Tunra Ltd at the University of Newcastle; Insearch at the

NSW Institute of Technology; and the Technology Research Centre at the Preston Institute of Technology.

CONSULTANTS

30.3.18 The term 'consultant' in this area covers a wide range of services from those provided by skilled, experienced individuals to those provided by large, multi-disciplinary, international organisations. Typical of this latter group is Davy Pacific Pty Ltd, the Melbourne-based subsidiary of the international Davy-Loewy group. The Patscentre (PA Technology and Science Centre), which is a subsidiary of the international consultants, Personnel Administration, in conjunction with its Cambridge (UK) Laboratories, provides R&D support from the fundamental level to the production of a commercial prototype. The Commonwealth Aircraft Corporation's development and production resources are available, by arrangement, on something between a consulting and an extension service basis.

30.3.19 Several government agencies provide consultancy type services to industry. These include the Productivity Promotion Council of Australia (and particularly its Productivity through Technology Panel), the Industrial Design Council of Australia and the Materials Handling Bureau, which operate under the aegis of the Department of Productivity.

EXTENSION SERVICES

30.3.20 Technology transfer is very important for the well-being of industry in Australia and access to reliable and up-to-date information is essential for technology transfer. Apart from the efforts of individual companies, the staple services are provided by the Australian National Scientific and Technological Library (ANSTEL), part of the National Library of Australia, and the CSIRO Information Service. However, technical services for the metal industries do not compare with, for example, those for the agriculture-based industries. Several industry associations provide such services. These include the Aluminium Development Council, the Australian Institute of Steel Construction, the Australian Welding Research Association, the Copper and Brass Information Centre, the Australian Lead Development Association, and the Australian Zinc Development Association. Technology transfer is a major aspect of innovation and the Australian Innovation Corporation Ltd (AICL), coupled with its affiliate, Trans-Knowledge Associates, promotes the concept of 'Licensing Fairs'. These are held regularly overseas to promote the exchange of technology and such a Fair is planned for Sydney early in 1979. A recent initiative is the establishment of a pilot network to develop techniques and facilities for transferring technology in the metal trades area. This is a co-operative activity involving professional, industry and government organisations, and is supported by the Department of Productivity.

STANDARDS AND TESTING

30.3.21 Conforming with approved standards is vital to new development. New standards are continuously being formulated by the Standards Association of Australia (SAA). The SAA also provides library services covering all recognised overseas standards and specific standards information relevant to most individual organisations. Allied to standards is the matter of approved testing. The National Association of Testing Authorities (NATA) maintains a comprehensive register of approved testing facilities. There are now over 1,000 laboratories (mainly in the industrial sector) registered with NATA; these form a national testing network to meet the needs of government and industry. NATA was the first organisation of its kind in the world and several other countries have now followed Australia's lead.

TRADE ASSOCIATIONS

30.3.22 Several trade associations are active in Australia in providing information to the metal products area. In particular, most Australian steel foundries are members of the Steel Castings Research and Trade Association in the UK (SCRATA) and obtain technical information through this membership.

30.4 DESCRIPTION OF R&D ESTABLISHMENTS AND PROGRAMS

30.4.1 The main research establishments are briefly described below. Those described are not intended to form a comprehensive list but rather to give an indication of the size and scope of some of the more important establishments. The establishments described cover the Commonwealth Government instrumentalities, industry and institutions for tertiary education.

COMMONWEALTH GOVERNMENT

CSIRO

30.4.2 The CSIRO Division of Materials Science (formerly Tribophysics), at Parkville in Victoria, and at Adelaide, studies the properties, behaviour and utilisation of important classes of materials based on metals, alloys, and ceramics. Its work covers the development of catalysts for synthesis and interconversion processes with liquid and gaseous fuels, the development of materials of very high strength and resistance to severe environments, and the study and development of processes involved in materials useage and fabrication techniques. The Division is also active in

diecasting and collaborates with the Diecasting Institute of Australia. The Division now incorporates the Adelaide laboratory of the Materials Research Laboratories of the Department of Defence (with the exception of small groups concerned with testing and standards).

30.4.3 CSIRO's Division of Materials Science has a production technology program which develops new and improved fabrication methods and aims to improve the properties of metallic and related materials, having regard to the technology of their use. The program encompasses ferrous castings, forging, surface technology, welding, non-ferrous die casting, materials development, metal machining and electrography. The program has 35 professionals working in it and had a budget of \$1.06million during 1977-78.

30.4.4 The Agricultural and Forestry Engineering program of the CSIRO Division of Mechanical Engineering covers crop producing and harvesting, and tree harvesting as well as crop preservation. Work within the program includes studies on harvesting by developing agricultural machinery for special purposes, and developing machinery for harvesting trees. The program (not all of which relates directly to metal products and machinery) involves 10 research workers and had a budget of \$510,000 for 1977-78.

30.4.5 The Minerals Research Laboratories of CSIRO described in chapter 24 ('Mining Engineering and Mineral Processing') have a Process Metallurgy and Engineering program which covers hydrometallurgy, chemical structures and thermodynamics, and pyrometallurgy. The program aims to improve existing technology and to initiate new metallurgical processes. The program has a professional staff of 32 and had a budget of \$1.37million for 1977-78.

30.4.6 The CSIRO National Measurement Laboratory (NML) has facilities at Sydney and Cullgoora, NSW, and at Adelaide, SA. It is concerned with maintaining Australian standards of measurement of physical quantities and the means for relating measurements throughout the Australian community to these standards, a service essential to the precision machinery industries. It develops improved standards and methods of measurement in collaboration with national laboratories overseas and with the International Bureau of Weights and Measures, and calibrates standards and instruments, especially for verifying authorities designated by the NATA. NML gives advice and assistance to industry and other scientific laboratories in solving technical problems, especially those involving measurement. It also conducts research on the properties of materials.

30.4.7 NML's 'Measurement of Physical and Mechanical Quantities' program covers a wide field. It includes developing improved length-measuring facilities using lasers, investigating the metrological aspects of precision surfaces, calibration of reference vibration transducers by interferometric techniques, accurate measurement of flow in pipe lines, dynamic testing of machine tools, developing reference hardness testing equipment, and applying holography to dimensional measurement. The program occupies a staff of 28 professionals and had a budget of

\$1.48million for 1977-78. The National Measurement Laboratory's 'Measurement of Thermal and Optical Quantities' program establishes, maintains, improves and disseminates standards of thermal and optical quantities. The program encompasses temperature measurement, optical radiometry, optics and optical standards of length. The program employs a professional staff of 31 and had a budget of \$155,100 for 1977-78.

30.4.8 Other Divisions of CSIRO whose programs comprehend activities related to metal products and machinery (and which are discussed in more detail in the appropriate chapters of this Volume) include: the Division of Forest Research (development and introduction of tree-harvesting machines); the Division of Mechanical Engineering's Solar Engineering Unit (development and demonstration of large-scale solar heat systems); and the Wool Research Laboratories (fibreprocessing equipment, new shearing equipment and new instruments for measuring the properties of wool).

Department of Defence

30.4.9 The Materials Research Laboratories at Maribyrnong (Victoria) provide a wide range of scientific and technical support services to the Commonwealth Department of Defence. The Laboratories also support the defence production base. Skills exist in the fields of chemistry, physics and metallurgy, and the Laboratories have special knowledge in the fields of fine grinding and metal polishing. In the metal products and machinery area, there are 17 research staff (8 professionals) and the annual R&D budget is \$448,000.

30.4.10 The Defence Research Centre, Salisbury (SA), which was formerly the Weapons Research Establishment (WRE), maintains R&D programs on metal products, industrial machinery and equipment and instruments (including optical, electro-optical, infra-red, electro-mechanical, computer-aided and photo-lithographic equipment). Major ongoing R&D activities are aimed at producing new navigation and surveillance equipment. In these areas, the Centre has 22 professional staff, 42 technical staff and 28 trades personnel (wholly committed to supporting R&D activities) and an annual R&D budget of \$2.39million.

30.4.11 The Engineering Development Establishment in Maribyrnong (Victoria) provides a source of development engineering and equipment design to the Defence Department. It designs, redesigns and modifies equipment to meet Defence Force and Department requirements. At present, development engineering activities centre on ground vehicles, target surveillance, navigation, guided and unguided weapon systems, electronic warfare, communications, explosives and general engineering. There are 80 professional staff, and 215 support staff and the annual budget is \$6million.

Department of Productivity

30.4.12 The R&D activities of the Government Aircraft Factory at Port Melbourne (Victoria) are described in Chapter 25 ('Aeronautics and

Aerospace'). However, some activities relevant to this chapter, involving about six professional staff, include metal bonding, chemical milling of aluminium alloys, ultrasonic non-destructive testing, automatic riveting, argon arc welding and numerically-controlled machinery.

30.4.13 The Ordnance Factory at Maribyrnong (Victoria) is a large engineering factory engaged in the manufacture of a wide range of defence equipment. The specialised skills of the factory are also available to industry. Major development projects centre on the development of new machinery for the production of defence equipment. There are 7 professional production development staff, 11 support staff and the annual development R&D budget is \$230,000.

30.4.14 The Ordnance Factory at Bendigo (Victoria) is responsible for producing, overhauling and repairing a large range of defence machinery. Production development activities are aimed at increasing factory capability. Present projects include the development of a high-velocity hydraulic pipe-flushing system, new welding systems and new deep-hole drilling techniques. The development budget is \$100,000.

INDUSTRY

30.4.15 The metal products and machinery industries encompass a very large and diverse group of organisations. The list of firms mentioned below is far from comprehensive and is intended only to provide information on the larger firms that are representative of the industry.

30.4.16 Comalco Ltd has research laboratories at Bell Bay, Tasmania, and Thomastown, Victoria, which employ 17 professional researchers and 11 technical support staff. The Thomastown laboratory has analytical and metal sections, and has a foundry and some provision for pilot plant work. The analytical section carries out some work on exploration and product analysis but is mostly concerned with experimental analysis for research. The metal section is involved in metal testing with some research in the metal area. Research work at Bell Bay is carried out on alumina reduction, alloy development and casting. The company's R&D activities involved expenditure of some \$1.35million during 1977-78.

30.4.17 International Harvester Australia Ltd has research laboratories at Geelong, Victoria, which include a prototype design office, and laboratories for testing rigs and prototypes. The company also operates a proving ground at Anglesea. The Product Engineering Department of the company employs 54 professional researchers and 113 technical support staff.

30.4.18 The Broken Hill Proprietary Company Ltd (BHP) operates corporate research laboratories at Shortland, NSW, and at Melbourne. It also has works research laboratories at Newcastle, Port Kembla and Whyalla. These laboratories employ approximately 500 people of whom 175

are graduates. A total of 155 people are employed in the metal products, machinery, and equipment areas. The major research on steel development and on the applications of steel is undertaken at the Melbourne and Port Kembla research laboratories. New steels are continually being developed to meet the requirements of industry, particularly in the flat product area, and a significant group is involved in tin-plate research. Other work is carried out in areas of metal-forming, free-machining steels, rails, steel rail-road sleepers and welding.

30.4.19 Repco Research Pty Ltd, a division of Repco Ltd, is located at Dandenong, Victoria, and employs 60 people working on the development of technology-based opportunities (for Repco) and giving technical support to existing Repco operations. Facilities available include a testing laboratory for engines and engine parts, analytical and industrial chemical laboratories, an electronic development laboratory, and a mechanical engineering laboratory for engineering and process development as well as for product development. Repco Research also has an eurhythmics laboratory concerned with the design and production of physical education and medical equipment. The laboratories have a record of co-operation with CSIRO in the commercialisation of CSIRO developments, for example, the self-twist spinner.

30.4.20 Rheem Australia Ltd has a research laboratory at Rydalmere, NSW, employing 9 professional researchers and 12 technical support staff. The laboratory is a technical research centre for the company and the R&D activities are oriented to serving its operating divisions which, in the metals area, deal with containers, appliances and fabricated metal products.

30.4.21 John Lysaght (Australia) Ltd operates a Research and Technology Centre, employing 51 professionals with 57 technical support staff (including 34 trainees), together with a Product Development group employing 7 professionals and 9 support staff. Laboratories are located at Port Kembla and at Newcastle. In addition to background work in various applied science and engineering areas related to the Company's present and future interests, they perform development work on present products and processes for their improvement, and the development of new products. Projects cover production, and properties, of sheet steel materials, including basic properties, metal and organic coatings, process simulation and computer control, specific on- and off- line measuring systems, field corrosion testing, sheet metal forming and development of new sheet metal products. The company has developed special knowledge and expertise in these areas.

30.4.22 McPherson's Ltd is involved in the manufacture of pumps (including iron and steel castings), programming aids and interfacing for numerically-controlled machine tools, friction materials, metal-cutting tools, fasteners, files and cutlery. The major portion of R&D for McPherson's is carried out by McPherson's Research and Development Pty Ltd, although there is also a Pump Design Group. The R&D objectives cover design and development of new products, improvements to existing products, and development of new production plant and processes. The R&D activities

employed 19 professionals with 16 technical support staff during 1976-77, with a budget of \$719,000.

30.4.23 The Commonwealth Industrial Gases Ltd carries out its R&D work on a decentralised basis. The activities cover gas and electric welding and cutting equipment, welding consumables, medical and safety equipment, and equipment associated with gas processes. The company employs a total of 72 R&D staff, including 28 professional researchers. Expenditure on R&D activities during 1977-78 amounted to \$2.21million.

30.4.24 Wormald International Ltd has a world-wide R&D budget of approximately \$4million. Of this, about \$1.5million is committed in Australia to product and systems R&D with some 30 professionals involved full-time and part-time. The end-products of Wormald's R&D work are fire protection and detection systems, security installations, pumps and valves. There is considerable international exchange of R&D results within the Wormald International Group. Some use is made of manufacturing licence agreements on pumps and valves to provide specialised product information in Australia from licensed companies outside the Wormald Group.

30.4.25 Siddons Industries Ltd has two main research establishments, at West Heidelberg and at Croydon in Victoria, and has approximately 25 people engaged in research activities with a budget in the vicinity of \$500,000 per annum. The projects relate to new and improved products in the company's existing fields of manufacture, as well as R&D in new fields such as solar energy systems.

30.4.26 Metal Manufacturers Ltd is the principal Australian producer of copper and aluminium rods and wires for the cable and telecommunication industries, of bare-stranded over-head conductors for power authorities, and of copper and copper alloy tubes for the plumbing industry and for refrigeration, heat exchangers and other end-uses. The company's main works are located at Port Kembla (NSW), with branch factories operating at Maribyrnong (Vic), Strathpine (Qld), and Melville (WA). The technological staff are engaged principally in process control and quality control of finished goods and in maintaining production facilities. A proportion of their time is spent in R&D. The company employs 9 professional scientific staff (metallurgy, chemistry, physics) with 14 technical support staff, and 8 professionals with 11 technical support staff in the engineering field. R&D expenditure of around \$765,000 annually covers salary cost, library facilities and the sponsoring of local and overseas R&D programs.

30.4.27 Austral Bronze Crane Copper Ltd produces rolled and extruded copper and copper alloys and rolled aluminium alloys at three locations around Australia. It employs 10 professionals, with a number of technical support staff, mainly on process and quality control. However, about half this group's time is spent on improving existing, and developing new, processes and products. A large amount of work has been directed toward anti-pollution matters in recent years. A team of six professional engineers, with a number of draftsmen, is engaged on designing and developing equipment with a large proportion of their time directed toward

improving electrical and electronic controls. The company contributes to the British Non-Ferrous Metals Technology Centre in England, and to a CSIRO project on ceramic extrusion dies.

30.4.28 ACI Technical Centre Pty Ltd, in Sydney, is the research and development centre for Australian Consolidated Industries Ltd. It employs 125 people including 40 professionally qualified industrial research and development staff. The overall activities reflect the basic manufacturing areas of the company and can be generally related to two main product types - packaging materials and building products. These products in turn encompass a broad spectrum of materials including glass, metals, plastics, surface coatings, ceramics and papers. The ACI Technical Centre has an extensive analytical and testing facility. Activities related to metal products and machinery include fabricated metal products and sheet metal products, in both packaging and building products areas; the development of process control equipment for the manufacturing operations; and improvements to the performance of machinery components.

30.4.29 Simpson Pope Ltd directs its R&D effort towards the appliances, electrical equipment, and irrigation areas. It is mainly aimed at improving existing products but is also concerned with developing new products where most of the work is experimental development with some applied research being done on processes, e.g. enamelling. The 13 professional researchers and 57 technical support staff are involved in developing electric motors for specific purposes, reducing noise in domestic appliances and air conditioning equipment, and developing improved products generally.

30.4.30 Chrysler Australia Ltd has a Product Engineering Division at Clovelly Park (SA) employing 172 professional researchers and technical support staff. The R&D effort is concerned with the design and development of components and assemblies for the production of a range of passenger and commercial vehicles; the activity results in engineering specifications to enable manufacture, testing and approval of the various components for production assembly. Much of the design and development work is needed to adapt overseas Chrysler designs to meet the operational and environmental conditions existing in Australia. Continual investigation and development is carried out to improve performance and durability and to ensure safe operation of vehicles. Application of new materials and processes are continually under review.

30.4.31 General Motors-Holden's Ltd has a technical centre at Port Melbourne, and a proving ground (including a safety and emissions testing centre) at Lang Lang, Victoria. The technical centre has a Product Engineering Department, which includes 348 engineers and technical staff engaged on R&D programs. The proving ground complex is the largest and most advanced in Australia, and employs 27 research staff. The principal activities are directed to the design, development and testing of passenger cars and light commercial vehicles for the Australian and export markets, before releasing for manufacturing. Research for forward model programs is continuous, and includes projects on use of new materials and processes in the context of vehicle performance, fuel consumption, handling, durability and safety.

30.4.32 The Ford Motor Company of Australia Ltd employs 300 professional researchers and technical support staff. The staff are mainly involved with developing new products, improving current products, and developing ways to comply with government regulations. The company commits some 10% of its R&D resources to upgrading and developing manufacturing processes and technologies.

30.4.33 The ANI Corporation Ltd at Lidcombe, NSW, directs its R&D effort toward iron and basic steel products and light metal manipulation, industrial machinery and equipment, and fabricated structural metal products.

30.4.34 The Broken Hill Associated Smelters Proprietary Ltd has research programs aimed at developing new technology both in the areas of process and finished product (consumer development) for non-ferrous metals. The company employs 21 professional research workers and 11 technical support staff to work in the area of non-ferrous metal basic products. The R&D program involved expenditure of some \$1.44million during 1977.

30.4.35 Tubemakers of Australia Ltd has research laboratories at Mayfield and Yenora in NSW, and at Kilburn in South Australia. The R&D program encompasses iron and steel basic products, fabricated structural metal products, automobile parts, corrosion protection, waste disposal, materials handling, non-destructive testing, and agricultural and recreational equipment. The R&D effort is directed toward developing new or improved processes and products; the company employs 12 professional researchers and has 11 technical support staff.

30.4.36 The Commonwealth Aircraft Corporation Ltd at Port Melbourne carries out development work based on government funded programs in the area of aviation for defence. However, on July 1, 1978 the technical development resources of the Corporation were reorganised with a major aim of providing non-defence development facilities. Following the guidelines of corporate objectives drawn up in 1977, this non-defence development work will encompass the development of products or processes embodying the high levels of technological skills gained by the Corporation's engineering team in their work experience on defence aviation. It is anticipated that these moves will result in a greater proportion of the total work-load coming from sources outside defence. The non-defence work will have a high technology base and, consequently, a high development input. The Corporation's 25 professional researchers and 40 technical support staff are mainly concerned with fabricated, structural, metal products; computer-aided design; complex metallurgy (as it relates to high temperature aircraft engine duties); and to precision foundry products, aircraft fatigue analysis, and electronics.

30.4.37 Hills Industries Ltd employ a total of 30 R&D staff (6 professional) in South Australia. Their work is directed towards improving production processes and to developing new products and components for use in the consumer durables area. Production activities include tube production, light engineering and finishing processes. Main product groups

embrace domestic type products, automotive exhaust systems and communication antennae.

30.4.38 Chamberlain John Deere Pty Ltd have research laboratories at Welshpool in Western Australia and employ a total of 35 R&D staff (5 professionals) in the areas of fabricated metal products, industrial machinery and equipment, and tractor and farm equipment.

30.4.39 Hawker de Havilland Australia Pty Ltd have development centres at Lidcombe, Homebush Bay and Bankstown (NSW) and employ 18 development staff (10 professional) involved in a range of development activities in support of their involvement with the transport and aerospace industries. The company's role and activities are also described in Chapter 25 ('Aeronautics and Aerospace') and Chapter 35 ('Transport').

30.4.40 Massey-Ferguson (Australia) Ltd operates R&D facilities at Melbourne and Bundaberg. It employs 54 R&D staff (18 professionals) on a range of programs in the farm machinery and equipment area. The company is particularly active in developing new machinery for harvesting sugar cane and grains and for general planting of new crops.

30.4.41 Other industrial organisations active in R&D in the metal products and machinery area include Containers Ltd who have 20 R&D staff (5 professional) involved with work on sheet metal products. Rocla Industries Ltd employ 15 R&D staff (6 professional) working mainly on the technology of concrete products and the associated production of machinery and equipment, and Alcan Australia Ltd is engaged on R&D programs with non-ferrous basic metal products and fabricated metal products particularly in the transport equipment, and building and construction fields. Vickers Research Pty Ltd employ 2 professional R&D staff (and support staff as required) on steel products, transport equipment and industrial machinery while Malleys Ltd have research laboratories at Auburn (NSW), Woolloongabba (Qld), Sunbury (Vic) and Kilburn (SA) with an R&D staff of 62 (4 professionals) who are engaged in work mainly associated with appliances and electrical equipment. ARC Industries Ltd employ 9 R&D staff (3 professionals) to support their activities in the fabricated metal products and industrial machinery areas; the Australian Gaslight Co employs 8 R&D personnel (4 professionals) working on new and improved appliances and electrical equipment and Qantas Airways Ltd, employs 38 staff (30 professionals) engaged in some R&D activities associated with aircraft structure, power plants and mechanical systems. Johns Perry Ltd, employs nine R&D staff in the machinery area, particularly in activities associated with lift-control equipment.

TERTIARY EDUCATION INSTITUTIONS

Note: The work at the institutions mentioned below is intended to be illustrative rather than comprehensive.

30.4.42 The Faculty of Engineering at the University of Sydney has 20 academic and professional staff together with 15 technical support staff, who work in the field of metal products and machinery. The R&D program includes the design, testing and analysis of fabricated metal structures and structural elements; investigation of corrosion, fatigue and strength of metal products; the design and analysis of machinery, and energy conversion.

30.4.43 The Faculty of Engineering at the University of New South Wales has some 40 professionals and 30 technical support staff who spend approximately one third of their time, on average, carrying out R&D in the metals products area. R&D work encompasses fabricated, structural, metal products, sheet-metal products, other fabricated metal products, motor vehicles and parts, other transport equipment; and industrial machinery and equipment.

30.4.44 The Department of Mechanical Engineering at the University of Newcastle has 16 professional staff engaged in (part-time) research and 12 technical support staff. Most of their work in the metal products area is concerned with improving existing products and processes.

30.4.45 The New South Wales Institute of Technology is primarily a teaching institution, but staff of its various schools, including Mechanical Engineering, are encouraged to undertake consulting work. Seven professional staff of the School of Mechanical Engineering provide expertise in areas connected with metal products and machinery, including dynamic behaviour of transport equipment, design of mining machinery, conveyors and materials handling equipment, and testing and materials property measurement.

30.4.46 The Departments of Mechanical Engineering and of Metallurgy in the Faculty of Engineering at the University of Melbourne have an R&D program in the metal products area which includes both basic and applied research. Basic research investigations cover turbulence, heat transfer, information processing, creativity and industrial innovation, and fatigue crack propagation. The more applied research includes manufacturing methods, energy conversion, motor vehicle dynamics, and human engineering. In addition, a small but significant proportion of the work is concerned with failure analyses. The 15 professional staff and 8 technical support staff have an annual budget for research related to metal products and equipment of approximately \$250,000.

30.4.47 The Department of Mechanical Engineering at Monash University has, since its inception, been actively engaged in R&D work in the metal products and machinery area. The present work covers areas in the design of products and machinery, optimisation, fluid logic and automation, fluid dynamics, heat transfer, kinematics and mechanisms, control of industrial noise, dynamics of machinery and vibration, applied mechanics, metal forming and metal removal processes. A significant contribution made in the Department is the extensive application of the computer in data collection and processing, and in the analysis and solution of problems

associated with metal products and machinery. Some 20 academic staff and 14 technical staff are directly or indirectly engaged.

30.4.48 The Department of Mechanical and Production Engineering at the Royal Melbourne Institute of Technology is undertaking investigations into several areas of metal fabrication. Specific areas include the quality control of production (and the level of quality control required) with investigation into the switching rules between different levels; and maintenance strategies and maintenance effectiveness, with an investigation of the diagnosis of maintenance requirements. The Department of Metallurgy is undertaking a program in the development of welding technology with specific interest in welding imperfections, welding control and real-time control of welding processes for weld quality. Research into corrosion and metal finishing is also being undertaken.

30.4.49 The Department of Mining and Metallurgical Engineering at the University of Queensland conducts a range of R&D projects largely concerned with properties of metals, including corrosion, properties of alloys (including machining, wear resistance, thermal and tensile properties), welding, high-strength stainless-steel products, and fatigue of structural materials. About 10 (teaching and research) staff are involved on these projects.

30.4.50 The Department of Mechanical Engineering at the University of Adelaide conducts both fundamental and applied research in the metal products area with specific attention to photographic, professional and scientific equipment. The 15 professional researchers and 11 technical support staff devote approximately 70% of the research time to developing new products or processes. Improving existing products or processes absorbs 20% of the time while the remaining 10% is devoted to adapting technology developed elsewhere.

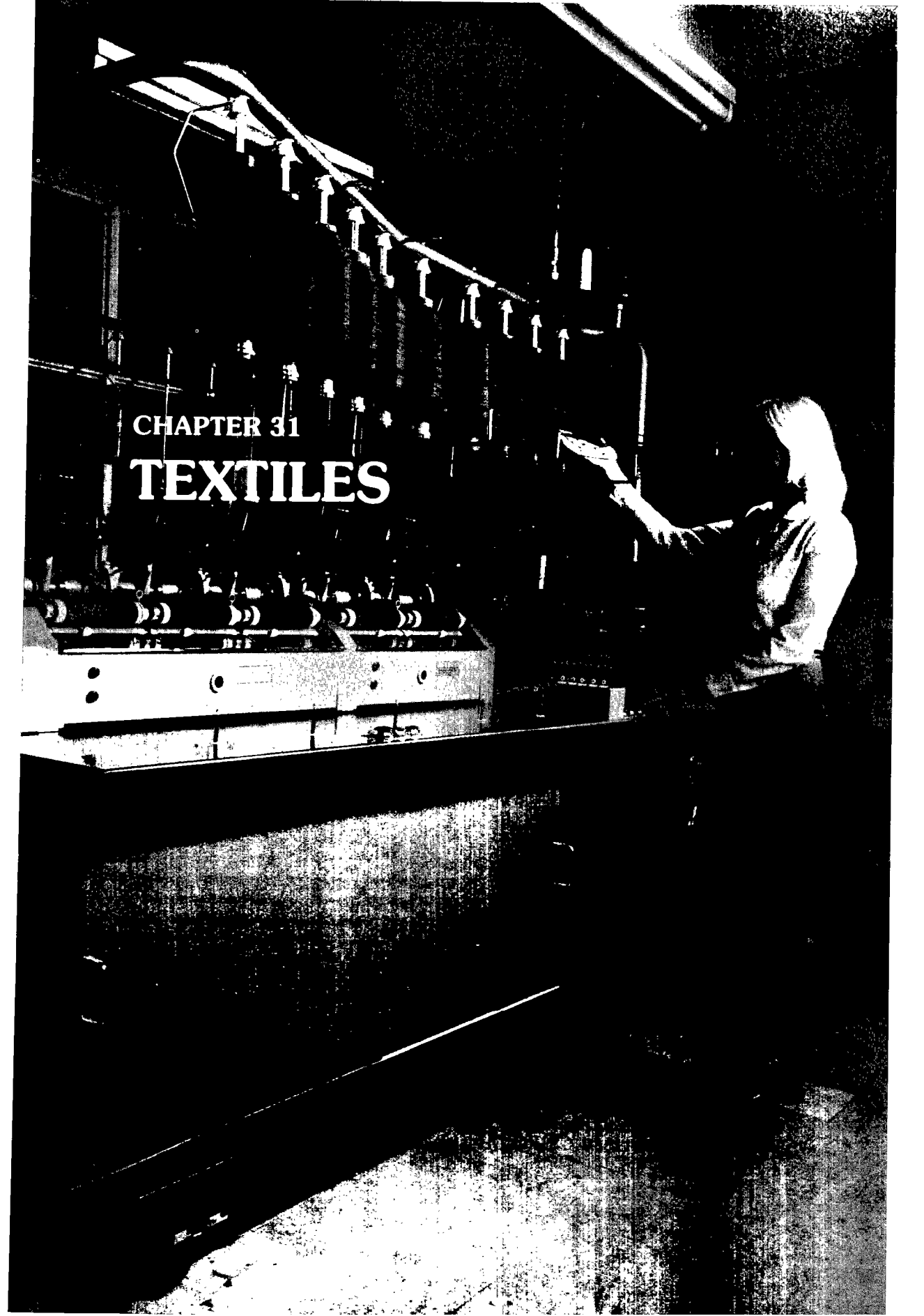
30.4.51 The Department of Mechanical Engineering at the University of Western Australia has five professional researchers and two technical support staff working in the iron and steel basic products, and the non-ferrous metal basic products areas. R&D expenditure during 1977-78 amounted to \$60,000.

30.4.52 The Metallurgy Department of the Western Australian Institute of Technology has laboratory facilities in Perth and Kalgoorlie in Western Australia. R&D resources, amounting to the equivalent of one full-time professional researcher and half a technical support person, are directed towards iron and steel basic products, non-ferrous metal basic products, and the fabricated, structural, metal product areas.

30.4.53 The Department of Civil and Mechanical Engineering at the University of Tasmania has five professionals and three technical support staff who spend approximately one-third of their time on R&D in the metal products area. R&D work includes shrinkage effects of welding, strength of metal cylinders and frames as well as some failure analysis, and machine vibration work.

NOTES AND REFERENCES

1. Australian Bureau of Statistics, 'Australian Standard Industrial Classification' Preliminary Edition, Volume 1. Australian Bureau of Statistics, Canberra, 1969. Catalogue No. 1201.0.
2. 'White Paper on Manufacturing Industry', Australian Government Publishing Service, Canberra, 1977.
3. 'Resource Productivity Meeting: Summary and Main Points', Department of Productivity, Melbourne, August 1977.
4. 'Iron and Steel Resource Productivity: Report of Second Meeting', Department of Productivity, October 1977.
5. Australian Bureau of Statistics, 'Manufacturing Establishments, Summary of Operations by Industry Class 1974-75' Australian Bureau of Statistics, Canberra, 1977. Catalogue No. 8202.0.
6. Australian Bureau of Statistics, 'Foreign Control in Manufacturing Industry. Study of Large Enterprise Groups 1975-76', Australian Bureau of Statistics, Canberra, 1976. Catalogue No. 5315.0
7. Report of the Independent Inquiry into the CSIRO. Australian Government Publishing Service, Canberra, 1977.



CHAPTER 31

TEXTILES

Photograph: The CSIRO/Repco Mark II Self-Twist Spinner produces worsted yarns at speeds of 300 metres/minute compared to 15-20 metres/minute on conventional ring spinners.
(Photograph courtesy CSIRO Division of Textile Industry).

CHAPTER 31

TEXTILES

31.1 BACKGROUND

DEFINITION OF AREA COVERED

31.1.1 The area covered in this Chapter comprises all aspects of textile production, including preparatory processes, yarn manufacture, fabric manufacture and dyeing and finishing. It does not cover the production of clothing or other assembly of fabrics, except for R&D into fabric structure and properties of significance in the making-up and in the end use of the fabric or fabric assembly, and R&D carried out in textile companies which process to the garment stage.

31.1.2 The bulk of the R&D effort in Australia is concentrated on wool textiles and, in this context, pre-mill procedures, including objective measurement, are receiving considerable attention; this work has been included. Basic research into the physical and chemical properties of the wool fibre is also included, because of its long-term significance in the development of future technology.

SIGNIFICANCE OF THE TEXTILE AND RELATED INDUSTRIES

31.1.3 The Australian textile and the related clothing and garment industries employ about 110,000 people, or approximately 10% of the total employment in the manufacturing industries sector. For the clothing industry, a large proportion (20-25%) of the consumption is imported in the form of cloth (piece-goods), or as semi-finished goods. The textile industry (as defined in 31.1.1) has an employment of approximately 40,000 and an annual turnover of more than \$1,200million with a value added of \$500million, whilst the clothing industry employs a further 70,000 people (approximately) and has an annual turnover of \$1,500million. The textile and clothing industries consume about 250 million kilograms of fibres, comprising approximately 46% man-made or synthetic, 42% cotton, 10% wool and 2% flax.

31.1.4 Approximately 800 establishments are involved in the textile industry throughout Australia; they are largely concentrated in Victoria and NSW, and these States account for approximately 83% of the establishments and of the employees. In NSW and Victoria, a significant proportion of the employment in the industry (26% and 22% respectively) occurs outside the capital city areas.

31.1.5 The Australian wool clip, about one-third of the total world production, amounts to approximately 700 to 750 million kilograms of greasy wool annually, with a value in excess of \$1,000million, while the annual production of Australian cotton has increased to about 30 million kilograms, with a value of more than \$30million; and in fact this cotton production is more than sufficient to supply the local cotton-processing industry, and a proportion (20-25%) is now exported. However, in view of the importance of wool in the Australian economy and the dominant position held in the international wool market, it is logical that the bulk of Australian R&D in this field is devoted to wool.

31.2 ORGANISATION, POLICIES and FUNDING

FUNDING AND EXPENDITURE

31.2.1 Table 31.1 gives the breakdown of total research and development expenditure. It can be seen that CSIRO accounts for about 70% of the total expenditure of \$9.97million, industry for about 20%, and tertiary education institutions for 10%. The CSIRO Division of Textile Industry provides approximately half of the CSIRO research effort on textiles.

TABLE 31.1
DISTRIBUTION OF TEXTILE RESEARCH EXPENDITURE
(1976-77)

<u>Organisation</u>	<u>Expenditure</u> <u>(\$million)</u>	<u>Sub-Total</u> <u>(\$million)</u>
Commonwealth Government		
CSIRO Division of Textile Industry	3.30	
CSIRO Division of Textile Physics	1.89	
CSIRO Division of Protein Chemistry	1.44	
Other	0.28	
	<u>6.91</u>	6.91
Tertiary Institutions		
School of Textile Technology, University of NSW	0.70	
School of Wool & Pastoral Sciences, University of NSW	0.26	
Other	0.10	
	<u>1.06</u>	1.06
Industry (estimate - see 31.2.6)	2.00	<u>2.00</u>
Total		<u>9.97</u>

31.2.2 The major proportion of tertiary education institution finance is expended at the University of NSW in the Schools of Textile Technology and Wool and Pastoral Sciences.

31.2.3 Prior to 1977-78, approximately 95% of CSIRO textile research funding came from the Wool Research Trust Fund (WRTF), with the remainder from Treasury appropriations. On 1 January 1978, about 60% of CSIRO wool research funding, previously provided by the WRTF, was transferred to consolidated revenue (see also 31.2.10). The WRTF provides approximately 70% of the funds for textile research in tertiary education institutions with the remaining 30% coming from the University of NSW (in terms of its staff and facilities). Company expenditure is internally funded, with a minor contribution coming from the Australian Industrial Research and Developments Incentives Board.

31.2.4 The WRTF accounts for about 80% (40% in 1978-79 - see 31.2.3) of the total funding and, in this context, the major role is played by the Australian Wool Corporation (AWC). The AWC's R&D responsibilities under the Wool Industry Act (1972) are to promote the use of wool and wool products through encouragement of research in connection with the production and use of wool. It is a function of the AWC to make recommendations to the Minister for Primary Industry concerning expenditure from the WRTF by organisations, other than CSIRO and the Bureau of Agricultural Economics (BAE), for research, development, extension and education related to the production or use of wool and wool products. The AWC's function in relation to expenditure by CSIRO and BAE is to advise the Minister on the applicability of the programs of both organisations to wool industry needs.

31.2.5 To facilitate its role, the AWC is served by a number of advisory committees in the specific areas of production, textile, economic and objective measurement research. One important committee, the Wool Research Allocations and Priorities Committee, has the task of examining and establishing priorities in the total research and development needs of the industry from production of the raw fibre through to the consumption of the end-product. This committee reviews the entire program supported from the WRTF in all organisations, including CSIRO and BAE, and comments on the priority of individual items of work in order to assist the Minister in arriving at a program budget from the fund. The total WRTF budget allocation of about \$16.5 million for 1976-77 was distributed so that approximately 48%, 44%, 3% and 5%, respectively, were allocated to wool production, textiles, objective measurement and economic research.

31.2.6 Table 31.2 lists the companies approached in the preparation of this chapter. The number approached was not sufficient to provide an accurate value for the total industry expenditure on R&D and the figure of \$2million (Table 31.1) is an estimate only. Expenditure on R&D varies widely from company to company, ranging from companies with large, formal R&D sections, to companies using production facilities and personnel to support their programs. Development work, in general, is directed towards improving production processes, devising new or improved products, and producing in Australia fabrics and effects selling well overseas; it is usually aimed at maintaining the competitive position of the company involved. Most of the effort is carried out on an individual company basis, although there are several collaborative programs with

overseas organisations. Many companies have access to overseas R&D information, either through parent companies or by arrangements with other overseas organisations.

TABLE 31.2

COMPANIES APPROACHED FOR INFORMATION

Fibremakers Ltd	Sarlon Australia Pty Ltd
Bruck (Australia) Ltd	Repco Ltd
Albany Felt Pty Ltd	Dodd & Co Pty Ltd
Carpet Manufacturers Ltd	Pacific Carpets International Pty Ltd
North Western Woollen Mills Ltd	Godfrey Hirst Australia Pty Ltd
Bradmill Industries Ltd	Minster Carpets Pty Ltd
Bond's Spinning Mills Pty Ltd	Homfray and Co Pty Ltd
Australian Sewings Pty Ltd	Macquarie Worsted's Ltd
Universal Textiles Australia Ltd	Morris Woollen Mills (Ipswich) Pty Ltd

POLICIES AND AGREEMENTS

31.2.7 Wool research, development and promotion are strongly linked, both in policy and in practice. The world-wide investment in wool textile R&D is co-ordinated by the AWC, other grower-country bodies and the International Wool Secretariat (IWS), and has been designed to meet the needs of wool users and end-product consumers. Textile research priorities are directed towards maintaining wool's competitive position in respect to other fibres. It is the policy of the AWC to encourage research projects in the following areas:

- process development: to increase the efficiency and versatility of textile processes which are specific to wool, and to solve problems associated with the performance of wool in manufacture;
- improved products: to impart improved or new performance characteristics to wool garments and fabrics and to develop new applications for wool products;
- physical and chemical studies: to explain the chemical and physical mechanisms involved in wool processing and to elucidate the chemical and physical structure of wool to provide a basis for the development of new processes.

The foregoing three areas, and the priorities within and between these areas, are currently under review.

31.2.8 The Wool Textile Research Advisory Committee, like its counterparts in New Zealand and South Africa, includes senior technical staff of the AWC, who are also members of the IWS R&D Committee; this Committee, which comprises representatives from the leading wool research laboratories, IWS and grower-country boards and corporations, makes recommendations on priorities and on the planning and co-ordination of the international wool textile R&D program; it plays a vital role, bearing in

mind the scope of the program and its many participants throughout the world. The Chiefs of the three CSIRO Divisions are members of this committee and are hence involved in the international co-ordination of research.

REPORTS AND POLICY STATEMENTS

31.2.9 Two relevant Industries Assistance Commission (IAC) Draft Reports have been issued recently:

1. Draft Report on Financing Rural Research, issued April 1976.
2. Draft Report on Textiles, Clothing and Footwear, issued August 1977.

31.2.10 The Rural Research IAC Report covers all aspects of financing and organisation of rural research in Australia and, as such, covers the organisation, financing, direction and control of the wool and cotton textile R&D activities of the CSIRO. The IAC highlighted some financial and managerial problems affecting the oldest and largest Rural Industry Research Fund, namely that covering wool research financed through the WRTF. Although the IAC's recommendation to transfer the funding of 60% of the wool research carried out in the CSIRO and BAE from the WRTF to consolidated revenue was implemented on 1 January, 1978, the Government's future contribution to wool research funding is still being reviewed.

31.2.11 The Textile, Clothing and Footwear IAC Draft Report, made available for examination and comment by the industry in August 1977, only briefly covers the significance of R&D and technology in the industry. The report concluded that, in general, the industry is technologically up-to-date.

31.2.12 The more general conclusions and recommendations, however, of the IAC's Draft Report on Textiles, Clothing and Footwear, and their subsequent implications for unemployment and related social considerations, caused considerable concern in the industry and led to the following statement by the Government in August 1977, concerning its policy towards the Textile, Clothing and Footwear Industry (Senator Cotton, Minister for Industry and Commerce, Senate Hansard, 17 August 1977):

The Government's basic position is that it regards efficient textile, clothing and footwear sectors as important and continuing parts of Australia's manufacturing industry. The significance of these sectors in terms of employment and related social considerations is fully recognised. We are determined - as are other developed countries - to preserve an efficient industry, not necessarily with the present composition, but with an essentially permanent character. The Government will apply what is termed in the White Paper on Manufacturing Industry 'sectional policies' to meet the special problems of the textiles,

clothing and footwear industries. Support will be provided for a defined period during which the industries concerned should make a real effort to improve their structure and efficiency and hence improve their long term outlook.

The statement also indicated that:

...the Government will ... arrange for the Minister for Productivity to enter into immediate discussions with representatives of the textiles, clothing and footwear sectors, and with the appropriate unions, to determine the potential scope and commitment to a program of productivity improvement.

31.2.13 Subsequent to the above policy statement, the Government announced on 22 November 1977 the setting up of a Textiles, Clothing and Footwear Review Committee, as part of the implementation of that policy.

31.2.14 A list of advisory bodies influencing the research carried out in the textile area is given in Appendix 31.1.

31.3 DESCRIPTION OF R&D ESTABLISHMENTS

COMMONWEALTH GOVERNMENT

31.3.1 The Wool Research Laboratories of the CSIRO are comprised of the Divisions of Textile Industry, Textile Physics and Protein Chemistry. Process and developmental research is carried out chiefly at the Division of Textile Industry; the Division of Textile Physics is concerned mainly with the physical properties of fibres and fabric, the objective measurement, and the packaging of wool; the Division of Protein Chemistry concentrates on the structure and chemistry of wool, colour stability of wool, and other chemical problems of the industry.

31.3.2 The three divisional chiefs, sitting as the CSIRO Wool Research Laboratories Committee, under the chairmanship of the Chief of the Division of Textile Industry, are responsible for co-ordinating and setting the overall pattern of research in the three laboratories. Selection of research topics and the emphasis given to each is decided by the individual chief in response to information received from other divisions of CSIRO, the IWS R&D Committee, the AWC, the textile industry and other interested bodies. Co-ordination between the Divisions is also maintained by periodic inter-laboratory conferences, by individual staff visits, and by the appointment of co-ordinators for specific inter-divisional projects.

31.3.3 Each division prepares estimates of expenditure each year on a program and sub-program basis. Before submission to the Minister of Science for approval, programs may be altered by the CSIRO Executive, which has the overall responsibility to ensure that the research is being directed towards areas of national priority.

31.3.4 The CSIRO Division of Textile Industry at Geelong, Victoria, is the largest of the three divisions, having a total staff of 217 (including 56 professional staff). Its annual budget for 1976-77 was approximately \$3.3million, of which about 90% was provided from the WRTF, with the remainder being provided by Treasury appropriations. Almost all the research is in the area of wool textiles, although minor programs involve cotton, textile machinery and noise from textile machinery.

31.3.5 The CSIRO Division of Textile Physics at Ryde, NSW, had a 1976-77 budget of approximately \$1.89million, devoted to wool textile research conducted by a staff of 120, including 39 professionals. The CSIRO Division of Protein Chemistry at Parkville, Victoria, had a 1976-77 budget of approximately \$1.54million, devoted to wool research conducted by a staff of 64 (32 professionals).

TERTIARY EDUCATION INSTITUTIONS

31.3.6 The School of Textile Technology at the University of NSW provides the only university-level courses for the training of textile technologists. Many of its graduates are employed within the three CSIRO divisions, the IWS, the AWC, and in the textile industry. The approximate total research budget (for 1976-77) is \$0.7million, of which about \$0.38million is the WRTF contribution, with the remainder being, in the main, the effective contribution by the University, in terms of the provision of staff salaries and facilities. The School has a total staff of 62, 25 of whom are financed from wool funds. Staff provided by the University include 10 academics, 5 professional staff and 22 support staff, whilst staff on wool funds consists of 6 professional staff and 19 support staff. Wool fund staff are wholly engaged in research, whilst university staff, on average, spend between 50 and 60% of their time on textile research. The School normally has between 20 and 25 postgraduate students carrying out research for higher degrees, almost all for the degree of PhD. About half these are financed from wool funds.

31.3.7 The School of Wool and Pastoral Sciences at the University of NSW is concerned with wool growing and is not directly concerned with textiles. There is, however, a group consisting of 8 professional staff and 7 support staff engaged in objective measurement research, where the total budget of \$0.256million consists of a contribution of approximately \$0.206million from the WRTF and about \$0.05million as the effective university contribution.

31.3.8 Additional wool textile research projects are being carried out in the School of Chemistry at Monash University, in the Department of Chemistry at the University of Melbourne, in the Department of Biochemistry at the University of Adelaide, in Deakin University, in the University of Western Australia, in the Melbourne Children's Hospital and by the Australian Wool Testing Authority.

INDUSTRIAL LABORATORIES

31.3.9 Within the industry itself, companies engaged in R&D often do not, except for a few of the larger companies, carry out their R&D by separate formally identified and financed R&D laboratories or sections, but use production facilities and personnel. Fibremakers Ltd, as an example of one of the larger companies in this area, and as the major synthetic fibre producer, appears to have the largest formally identified R&D activity, with a separate development department and laboratories, engaged essentially in applied development work on new or improved synthetic yarns for a wide range of apparel, domestic and industrial end uses. This covers the development and local application of new fibre manufacturing and processing technology, including technology arising from overseas affiliates, together with a contribution to new fabric developments with the textile industry. Funding of the R&D activity is wholly from within Fibremakers Ltd, with some assistance, in previous years, by grants from the Australian Industrial Research and Development Grants Board (AIRDIB).

31.4 DESCRIPTION OF MAJOR R&D PROGRAMS

31.4.1 Projects in research establishments and tertiary education institutions mainly involve wool and represent a co-ordinated approach to the problems involved. Industry programs, on the other hand, cover most fibres and a wide range of processing procedures and products. The two are therefore dealt with separately.

GOVERNMENT AND TERTIARY EDUCATION INSTITUTIONS

Note: Some university staff are not involved in full-time research. The numbers given for equivalent research staff on projects are rounded to the nearest integer.

Pre-mill procedures for wool

31.4.2 Harvesting, packaging and transport are also related to wool production, and research in these areas is undertaken by CSIRO, State departments of agriculture, universities and the Australian Wool Corporation (AWC). However, only work conducted within the wool textile research laboratories is described here.

31.4.3 Shearing of wool is a skilled, costly, labour-intensive operation. The Division of Textile Industry, with three researchers and a budget of \$205,000, is investigating the feasibility of automated shearing, which would reduce the labour content, and handpiece designs that could reduce the skill needed in shearing.

31.4.4 The Division of Protein Chemistry, with one researcher and a budget of \$39,000, is examining the factors controlling fibre development

in the follicle to provide a basis for defleecing by the use of biological agents. Both programs are expanding.

31.4.5 The CSIRO Division of Textiles Physics has a large program, involving 13 researchers and a budget of \$825,000, directed mainly at raw wool sampling and measurement, which is of importance in the overall program of objective measurement. It is aimed at replacing subjective assessment of wool properties, a change which would bring considerable benefits to both producer and processor. The work includes processing trials to determine the effects of classing procedures, of make-up of clip 'lines' and of greasy wool properties on processing performance and the properties of end products. Wool sampling equipment and an instrument for rapidly measuring the mean diameter of fibres, that has been developed in the Division are in use throughout Australia and overseas. An instrument for measuring staple strength is in an advanced stage of development and an improved instrument for very rapid measurement of fibre diameter is being evaluated.

31.4.6 The University of NSW, School of Wool and Pastoral Sciences' objective measurement program, involves 8 researchers and a budget of \$256,000. More than half the effort is related to developing and evaluating new methods of measuring fibre diameter, staple length (both based on instruments developed by CSIRO Division of Textile Physics), strength, colour and resistance to compression. Devices for each of these measurements are in an advanced stage of development. The other main project is a statistical survey of the variation of properties in Australian wool fibres; this is making a major contribution to the development of simplified clip preparation, together with procedures for sale by sample and test certificate.

31.4.7 The Australian Wool Testing Authority is investigating (budget \$46,000) new and improved test procedures, and the AWC is spending about \$236,000 on the extension and implementation of the objective measurement work.

Wool yarn manufacture

31.4.8 Wool has some distinct disadvantages compared with synthetic fibres, because of the lengthy and costly sequence of operations required to convert the raw fibre, contaminated by dirt and grease, into a finished yarn. Work in this area is largely directed towards developing improved machinery, processes and methods.

31.4.9 The CSIRO Division of Textile Industry program in this area (which extends into fabric manufacture) involves a budget of \$745,000 and 11 researchers. The work includes studies of detergent efficiency in wool scouring, of removal of vegetable matter, improved and less costly spinning methods and the processing of wool on the short-staple system.

31.4.10 The work has led to the CSIRO sliver carbonising method and to two important developments in spinning technology. One of these is self-twist spinning, which is now used world wide. Conventional spinning techniques are limited by the rate at which twist can be inserted. Self-twist overcomes this problem in a revolutionary way, by binding two

yarns together using a technique which develops a stable alternating twist structure. This has led to the production of the 'Repco' spinner, which has many advantages, including a dramatic increase in production rate (more than 15 times conventional rates). A more recent development is the 'Selfil' spinner, which uses the self-twist spinner principle to incorporate continuous synthetic filaments into the wool yarn to increase its suitability for knitting and other uses.

31.4.11 A considerable effort by the CSIRO is being placed on developing economic methods of spinning wool on the short-staple system. The cotton system accounts for a high proportion of the staple processing machinery market and there are several significant advantages to be gained if wool could be processed on the cotton system. This would provide new outlets for wool, including the new and very large, short-staple, manufacturing plants in Asia, and enable it to appear in a wider range of fabrics and markets.

31.4.12 The School of Textile Technology at the University of NSW has six researchers and an approximate budget of \$200,000 in this area. The major proportion of this effort is concentrated on dewatering, drying and carbonising. Several machines are at various stages of development. A high-intensity wool dryer is undergoing industrial trials and an industrial prototype acidiser is being constructed. Work, at present, is being directed towards a continuous centrifuge, for dewatering prior to drying, and to the neutralising stage of the carbonising process. The new carbonising process drastically reduces fibre damage and has the immediate potential of upgrading particular wools for processing on the worsted system, in addition to improving woollen carbonising. In addition, an investigation into fibre lubrication in spinning is nearing completion.

Wool fabric manufacture, structure and relationships to physical properties

31.4.13 Work is being carried out on fabric manufacturing techniques and on the relationship between the physical properties and structure of yarn and fabric. The work related to fabric properties and structure includes research devoted to understanding the relationships involved and to the physical properties of fabrics in general.

31.4.14 As noted in 31.4.9, the CSIRO Division of Textile Industry programs on yarn manufacture extend into fabric manufacture, since an understanding of how new yarns behave in fabric processing is essential. In particular, short-staple spinning requires the development of new fabric constructions.

31.4.15 The School of Textile Technology at the University of NSW has three researchers and six postgraduate research students involved in this area, with a total budget of about \$155,000. The major program is concentrated in the area of fabric structure and mechanical properties. The basic aim of the work is to identify, and to measure objectively, the significant fabric properties involved, to relate yarn properties and fabric structure to these properties, to examine effects of finishing and to relate fabric properties to the assembly of garments and to the final garment properties. Yarn and fabric bending testers, a fabric shear tester and reproducible techniques for the detailed investigation of seamed garment

assemblies and fabric buckling, have been developed and are being used to study industrial wool textiles, woven and knitted wool garments and garment processing.

31.4.16 The remaining effort is concentrated on quantifying the mechanics of the warp-knitting process, to relate knitting conditions to the performance of wool yarns during knitting and to fabric properties. Wool yarns have been successfully warp-knitted and investigations involving selfil yarns are in progress.

Colouration of wool fibres

31.4.17 Programs in this area are aimed at investigating problems associated with bleaching, whitening, dyeing and printing of wool, and at developing improved methods of colouration for wool and wool blends.

31.4.18 The CSIRO Division of Protein Chemistry has a large program in this area, employing 12 researchers with a budget of \$654,000. The work has concentrated on finding effective substitutes for chrome dyes, dyes capable of providing equal depths of shade in both wool and polyester fibres, suitable dyes for new printing procedures, and on saving energy in dyeing. Developments in this area are a new range of reactive dyes for wool, a number of light-fast, fluorescent, yellow dyes and a substitute for black chrome dyes suitable for use in continuous, loose-wool dyeing, as well as for conventional dyeing procedures.

31.4.19 Work on bleaching and whitening has concentrated on the catalytic photo-yellowing of wool by whitening agents and on the catalytic degradation of the whitening agents by the wool. The nature of the chemical reactions taking place when wool undergoes photo-yellowing is also being studied.

31.4.20 The CSIRO Division of Textile Industry, with a budget of \$411,000 and five researchers, is engaged in devising improved methods of dyeing, bleaching and printing of wool and wool blends. Because industry needs to respond rapidly to changes in fashion, emphasis is placed on systems which allow the material to be processed as far as possible before colouration. Particular interest is being centred on methods of continuous yarn dyeing, transfer printing techniques and on dyeing of wool and wool blends on machinery designed for other fabrics. Work is also being carried out on the dyeing of carbonised wool, on pretreatments for printing, on the printing of blend fabrics and on the influence of yarn dyeing on subsequent processing.

31.4.21 The CSIRO Division of Textile Physics, with a budget of \$305,000, and five researchers, is concerned with colour measurement and colouration processes. Improved, instrumental, colour matching of dyed fabrics is being examined, as well as aspects of reproducibility in the dyeing process. An improved computer program is being developed to produce dye recipes to match a given shade. A project started in 1976-77 is aimed at developing an apparatus for high resolution, jet printing of wool fabric and good results have been obtained with an early experimental rig.

31.4.22 The School of Textile Technology at the University of NSW, with five researchers and a budget of approximately \$105,000, is engaged in several colouration projects. A study into dyestuff aggregation is using a light scattering apparatus, which incorporates a laser beam to measure sizes of dye particles under varying conditions, in an attempt to overcome industrial dyeing problems thought to be related to dye aggregation. A project involving transfer printing with reactive, vaporisable dyes is about to begin in collaboration with the CSIRO Division of Textile Industry.

Improvements to final wool products

31.4.23 Co-ordinated sub-programs in the three CSIRO divisions, dealing with shrink-proofing, dimensional stability, wrinkling, moth-proofing and flammability, are aimed at improving the performance of consumer products. The effort at the Division of Textile Industry involves 23 researchers and a budget of \$1,209,000; that at the Division of Textile Physics, 9 researchers and a budget of \$352,000; and that at the Division of Protein Chemistry, 7 researchers and a budget of \$134,000.

31.4.24 Although methods for shrink-proofing exist, they do not appear to have been taken up widely by the textile industry. Cheaper methods, requiring less sophisticated control, are being examined by the three divisions. Particular emphasis has been placed on the application of polymers to the surface of the wool fibre and the work has included studies on adhesion mechanisms and the effect of the washing environment on shrink-proofing efficiency. The mode of action of different shrink-proofing treatments, particularly in relation to clothing comfort and to the wearing life of fabrics, is also being examined. The CSIRO Chlorine/Hercosett treatment has been adopted by IWS and is widely used on tops throughout the world. The Sirolan BAP process has been taken up by the local industry and is being released overseas by IWS. This is a simple, highly effective, pad-dry process for all types of wool and blend fabrics and does not need a pre-treatment such as chlorination. A newly prepared series of polyacrylates, that do not require prechlorination of the fabric, or mixing with other polymers as in the Sirolan BAP process, are showing considerable promise. Work on dimensional stability has established optimum blend ratios and knit structures for men's socks and these guidelines have been adopted by many Australian manufacturers.

31.4.25 The wrinkling propensity of wool has long been considered a problem and, in parallel with fundamental studies on wrinkling mechanisms at the Division of Textile Physics, attempts are being made at the Division of Textile Industry to improve recovery by using elastic polymers to modify the characteristics of fabrics and by using physical processes, such as annealing, to reduce the relaxation of fibres under stress. Annealing produces wrinkle-resistant fabrics, but conditions experienced in use, such as pressing after dry-cleaning, partially removes the effect. Conditions of annealing, and after-treatments, have recently been found that give large residual improvements, even after pressing, and attempts are being made to determine commercial conditions under which these treatments can be carried out.

31.4.26 The situation with respect to moth-proofing is potentially serious, due to the build up of strains of moths that are resistant to dieldrin. Commercially available alternatives tend to be expensive and, under some conditions, can present environmental problems. The Division of Textile Industry is carrying out studies on the absorption of insecticides from dyebaths and their removal from effluents, analytical procedures to ensure correct industrial practice, the potential of larvae to develop resistance to alternative insecticides, and the synthesis of wool-reactive insecticides. Work at the Division of Protein Chemistry is centred on investigations using compounds with anti-juvenile hormone activity, such as those which protect certain plants from insect attack.

31.4.27 Flammability research in CSIRO is aimed at understanding the mode of operation of flameproofing procedures for wool fabrics, at developing wash-fast treatments for wool, at devising satisfactory flammability tests and at formulating flammability standards. Work at the Division of Protein Chemistry has resulted in five Australian Standards for flammability of clothing and is providing information concerning the safety of drapes and carpets in public buildings. The Division of Textile Physics is primarily concerned with new standards and with instruments for measuring flammability of textiles which do not have the inbuilt bias against wool of many techniques developed overseas. The Division of Textile Industry is studying the influence of shrink-proofing processes on the flammability of natural wool and of wool treated for flame resistance.

31.4.28 The Division of Textile Industry is involved in work on abrasion resistance and on 'feel'. Abrasion resistance has been a shortcoming of wool fabrics and chemical treatments usually reduce their resistance to abrasion. Work is concentrated on relating the properties of the basic fibre, the yarn and the fabric to the abrasion test results, on relating existing test procedures to actual performance in service, and on chemically modifying the fibres to improve abrasion resistance. 'Feel' is important in consumer acceptance of a fabric and efforts are being made to obtain objective methods of testing, to evaluate changes caused by normal and specialised finishing sequences, to investigate the mechanisms involved and to manipulate handle by chemical treatments. The Division of Textile Physics is examining abrasion mechanisms, and is investigating the factors affecting clothing comfort; researchers have found that prickliness is sometimes related to the presence of a small number of coarse fibres.

Environmental impact studies related to wool

31.4.29 Significant problems can arise with the effluents from processes such as wool scouring, carbonising, mothproofing, dyeing and various finishing treatments. In particular, the problems generated by the effluent from wool scouring are of high priority. Machinery noise is also of significance.

31.4.30 The CSIRO Division of Textile Industry has five researchers with a budget of \$332,000 examining these problems. Of particular interest is work on a combined scour-effluent treatment plant with low

water consumption, where scour liquor is continuously treated and recycled. This completely new system, which shows commercial potential, is based on the discovery that if the scour-liquor concentration is allowed to build up, the efficiency of centrifugal separation increases. Commercial, 'Lo-flo', effluent treatment units are now under construction both in Australia and overseas. The Division of Textile Physics has one researcher with a budget of \$54,000 investigating the mechanism involved in this destabilisation effect.

31.4.31 The School of Textile Technology, University of NSW, has three researchers and four postgraduate students, with a budget of about \$150,000, examining methods of treating scour liquor effluent. A hot-acid, treatment plant has proved successful in mill trials in Australia and is at present being evaluated in the UK by the International Wool Secretariat (IWS). A pilot biological plant, involving a modification to the conventional, activated-sludge process, is in operation in a local mill. Studies are continuing into the extraction of grease from the sludge to the hot-acid process. Kinetic, micro-biological, biochemical, energy and economic investigations are continuing on the biological treatment process.

Strategic research on wool

31.4.32 Basic research on wool properties is important in providing the scientific foundation necessary for continued technological development in the future.

31.4.33 The CSIRO Division of Protein Chemistry has the largest program in this area, with about 10 researchers and a budget of \$620,000, carrying out research on the chemistry and structure of wool. This includes biophysical studies to determine histological and sub-cellular structure of keratin. Research is also being carried out on the characterisation of the individual proteins comprising the wool fibre. This work is yielding an overall picture of the arrangement of individual proteins in the structure. The effects of nutrition and of the breed of sheep on the proportions of the various constituent proteins present in the wool fibre are being related to variations in the physical properties of fibres (in co-operation with Textile Physics).

31.4.34 The Division of Textile Physics has five researchers, with a budget of \$274,000, carrying out research on wool physics. Studies include properties of fibres in compression, water sorption and desorption, mechanical properties of fibres containing internally deposited polymers, the effect of chemical reagents on the annealing of wool and the effect of shrink-proofing treatments on the fibre cuticle. The Division of Textile Industry, with two researchers and a budget of \$69,000, is working on polymer and surface chemistry - their fundamental work on ageing and wrinkling has been included under 'improvements for final products'. Strategic research, particularly in the CSIRO, has been reduced considerably in recent years.

31.4.35 A program involving two researchers, with a budget of about \$55,000, is being conducted into the mechanical properties of wool fibres at the School of Textile Technology, University of NSW, with particular emphasis on the mechanisms of ageing, wrinkling and the interactions of plasticisers with wool.

Other research

31.4.36 The CSIRO Division of Textile Industry has three researchers, with a budget of \$150,000, engaged on research related to Australian-grown cotton, which largely meets the local demand for the raw fibre. New, improved varieties developed by the CSIRO Division of Plant Industry are evaluated with respect to processing performance and product quality, in both micro-scale and pilot plant operations. Other projects study the effects of harvesting, dumping and ginning conditions on lint quality and respirable dust content; corona treatments; means of overcoming the disadvantages of low fibre maturity; and the development of a high-speed, self-twist, roving system. The Division of Textile Industry has one researcher, with a budget of \$68,000, working on paper yarns and their application.

INDUSTRY

31.4.37 Examination of the R&D programs within the Australian textile industry has shown that it can innovate and can improve its competitive position. It seems clear that, with the right climate and with appropriate incentives, the Australian industry could be a world leader in several areas. At the present time, the unsettled nature and uncertainty within the industry is providing a positive disincentive to innovation. It is estimated that real effort on R&D in the textile industry has declined by 40% over the last three years. Despite this situation, the industry is still managing to play a significant role in R&D, as indicated by the following examples of the efforts being carried out by a range of Australian companies. Some important programs are not described for reasons of confidentiality.

31.4.38 Fibremakers Ltd, as the major synthetic fibre producer, appears to have the largest, formal, R&D activity with programs aimed at developing new or improved processes and products from fibre forming polymers for a wide range of apparel, domestic and industrial textile end-uses. This covers the development and local application of new, manufacturing and processing technology for synthetic fibres in order to maintain competitiveness in the world scene. Staff employed in R&D consist of eight professional scientists and seven support staff. Fibremakers' Ltd major programs cover the development of new producer-texturing processes for synthetic yarns, via new, improved and more economic friction-texturing processes. Some of these technologies and processes are unique to Australia. Another major program centres on nylon carpet yarns, particularly suited for the new, and economically attractive, continuous printing processes for colouring carpets, that have been developed and introduced by the Australian carpet industry.

31.4.39 Bond's Spinning Mills Pty Ltd in previous years, through a highly organised R&D section, has managed to make very substantial productivity improvements, with the development of several fabric laying-up systems for cutting, with techniques for knitting open-end (OE) spun yarns, with a system of computer-assisted, colour matching, with a number of novel, sewing machine attachments and with an automatic, towel

cross-hemming machine. Considerable economic pressures, over the last few years, have forced this company to reduce their effort; however, they still continue to innovate. Work during the current year includes the development of techniques to enable OE yarn to be woven on Sulzer terry machines (a world first), the investigation of the effects of rotor speeds on OE spinning and OE yarns (in conjunction with the overseas machine builder) and the continued development of fluidic and electronically controlled sewing machine attachments.

31.4.40 Bruck (Australia) Ltd which contributes to the Shirley Institute (UK) program on dyeing and finishing is making very significant efforts, particularly in finding out how to produce fabrics and effects already being made overseas. In the field of curtain fabrics, this company has made innovations both in fabric design and in the development of constructions and dyeing methods for piece-dyeing of three- and four-colour effects. A washable and dry-cleanable back-coating of crushed acrylic foam for curtain fabrics has been developed and open-width padding methods of dyeing have been evolved to replace rope dyeing. Present work also includes imparting flame retarding properties to drapes and upholstery fabrics, evaluation of dyestuffs and other wet processing chemicals, heat transfer printing and instrumental colour matching.

31.4.41 Bradmill Industries Ltd undertakes significant R&D on spinning, weaving, dyeing and finishing, and garment manufacture. Important developments in spinning include the manufacture of polyester-wool blends on the cotton system, the production of open-end spun yarns for specialised applications, and the development of polyester-cotton yarns for denim production. The company plays an active role in conjunction with the NSW Health Commission in overcoming problems related to cotton dust. Bradmill Industries Ltd has been a world leader in the development and production of polyester-cotton duck fabric, has pioneered the weaving of solid-woven belt ducks (where machine makers now produce looms to this company's specifications), and is making a significant contribution to reducing the problem of wool pack contamination by the use of polyester-cotton packs. The company has made a significant impact in water- and rot-proofing technology, particularly in relation to polyester cotton ducks, is involved in flame proofing and flame retardancy and is investigating the parameters involved in indigo dyeing. Fabric lubrication, to assist sewing performance and materials-handling techniques in garment production has received considerable attention.

31.4.42 Carpet Manufacturers Ltd is particularly concerned with R&D in the areas of: applications of new fibres to carpets, new yarn constructions, new dyeing and technology and new carpet constructions for specific end uses; carpet flammability, soiling properties and static electricity control; synthetic polymer yarns in carpet backings; back-coating materials and methods; and mothproofing techniques.

31.4.43 Morris Woollen Mills (Ipswich) Pty Ltd has made a major effort in the field of effluent control. This has involved the rebuilding of scouring machinery in co-ordination with efficient disposal, in order to maximise the gains achieved. In fabric finishing, particular attention is being given to flame retardancy of furnishing fabrics and drapes, and fabrics are being developed with washing performance which compares favourably with

dry-cleaning behaviour. Morris is continuing developments related to blankets and woollen screen fabrics for hospital use, in order to maintain stability and shrink-proof properties when subjected to the harsh laundering given to such fabrics.

31.4.44 North Western Woollen Mills Ltd is active in development of hospital and domestic cellular woollen blankets, of bonded fabrics for various end uses and of high speed dyeing of a single end of yarn by a pad/steam technique.

31.4.45 Repco Ltd, as the machine builder for the CSIRO self-twist and self inventions, has been heavily involved over the past three years in yarn structure and in the development of spinning techniques.

31.4.46 Macquarie Worsted Ltd has a research program aimed at devising a method for dyeing polyester tow and subsequently stretch-breaking in order to avoid the combing process. Work to increase the potential of the Repco Self-Twist Spinner is in progress.

31.4.47 Dodd and Co Pty Ltd is making significant contributions to handling techniques for raw wool. Albany Felt Pty Ltd has a significant investment in developments related to industrial textiles and fabrics.

31.4.48 Two major, Australian owned, carpet manufacturers, (Godfrey Hirst Ltd and Minster Carpets Pty Ltd) which do not have access to R&D results from overseas parent companies, are allocating substantial R&D resources primarily in the area of continuous printing and equipment development. In particular, Godfrey Hirst Ltd has developed a unique (and very successful) new colouration process for carpets. This process is now in commercial use.

EXISTING ADVISORY BODIES, COMMITTEES AND AUTHORITIES
IN THE TEXTILE AREA AND TEXTILE RESEARCH AREA

A. THOSE INFLUENCING WOOL TEXTILE RESEARCH PROGRAMS:

1. Australian Wool Corporation via:

(i) The Wool Research Allocations and Priorities Committee (WRAPC). This committee decides the target budgets for all work (except that carried out in CSIRO and BAE) in each of the research areas of production, wool harvesting, distribution, textiles and economics, to ensure a balance between the effort in the different research areas, in accordance with overall industry priorities. It prepares the overall research program (for work carried out outside CSIRO and BAE) for recommendation (through the AWC) to the Minister and provides comments (through the AWC) to the Minister on the CSIRO and BAE wool research programs. The committee comprises the chairman of each of the individual research advisory committees.

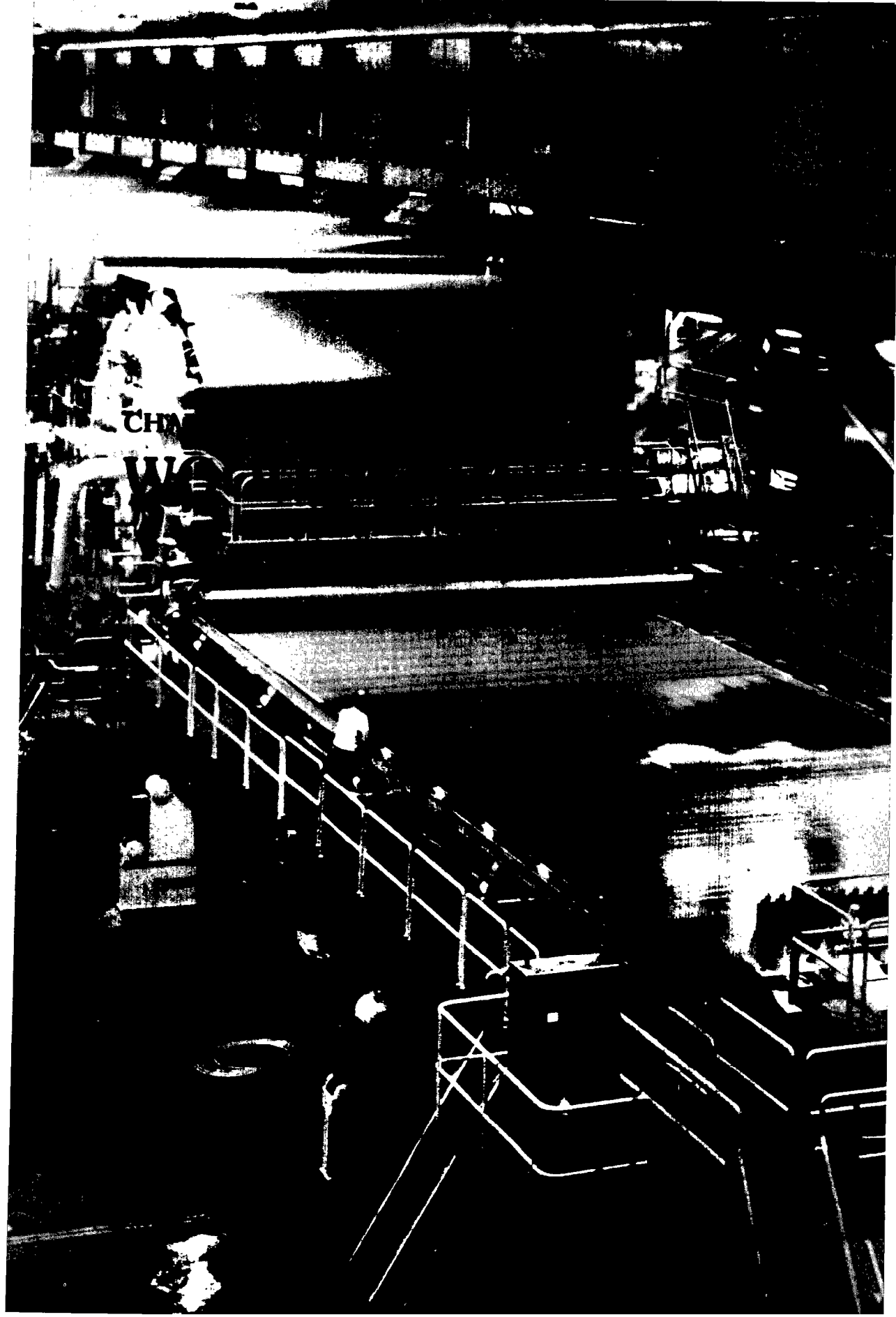
(ii) The Wool Textile Research Advisory Committee (WTRAC). This body allocates priorities within the wool textile research area on the basis of surveys by marketing and technical personnel within IWS, and after consultation with major industry processors and organisations involved in marketing wool and wool products. It makes recommendations to WRAPC on the (non-CSIRO) wool textile research program based on approved individual project applications. It also prepares comments for WRAPC on the CSIRO wool textile research program.

2. The Wool Research Review Committee, an independent group commissioned by CSIRO to determine those areas of the Australian wool industry that would benefit from research in the context of its (the wool industry's) total industrial, economic and social (including political) significance.

The report of this Committee is under consideration.

B. THOSE INFLUENCING TEXTILE POLICY:

1. Industries Assistance Commission, for example:
Draft Report on Financing Rural Research - April 1976
Draft Report on Textiles, Clothing and Footwear - August 1977
2. Australian Wool Corporation and the International Wool Secretariat.
Apart from the official inputs by WTRAC above, both these bodies collectively have an input to the Government.
3. The Textile Authority, established within the Temporary Assistance Authority, part of the Industries Assistance Commission. The Textile Authority, however, appears to have taken a lesser role in temporary assistance, in that now the IAC itself is being asked to provide interim reports in the textile area. Also, the new Textile, Clothing and Footwear Review Committee will be advising on quotas, etc. in the immediate future.
4. Textile and Apparel Industry Advisory Council, reporting to the Minister for Industry and Commerce.



Photograph: The new No. 4 machine at APM's Maryvale Mill. Built at a cost of \$45million, this machine is one of the most modern and versatile paper machines in the world. It incorporates all the latest aids to efficiency, some of which were conceived and developed in Australia.

(Photograph courtesy Australian Paper Manufacturers Limited).

CHAPTER 32

WOOD PRODUCTS

32.1 INTRODUCTION

DEFINITION OF AREA COVERED

32.1.1 The area covered is broadly based on Sub-Divisions C25 and C26 of the Australian Standard Industrial Classification (Australian Bureau of Statistics, 1975), and has been sub-divided as follows:

basic wood science; sawmilling; preservation; seasoning; quality testing; plywoods, veneers and other laminated wood products; particleboards; hardboards and insulating boards; furniture; wood residues, by-products and miscellaneous uses; pulp; paper and paperboard; paper and paperboard products; printing.

This Chapter does not discuss tree harvesting or export of wood chips, but does overlap Chapter 20 (Forestry) in matters relating wood properties to utilisation, and also Chapter 26 (Construction) insofar as strength tests on wood and the development of wood products for structural use have been included. The definition of R&D given in the Industrial Research and Development (IR&D) Incentives Act 1976 applies throughout this Chapter.

POLICIES AND AGREEMENTS

32.1.2 The FORWOOD Conference held in 1974 under the sponsorship of the Australian Forestry Council produced a plan to achieve nett self-sufficiency in wood resources by the year 2010, and made a number of recommendations relevant to R&D in the wood products industries. These were accepted by the Australian Forestry Council and passed to the Council's secretariat for referral to the relevant authorities. In summary, the recommendations relevant to this Chapter are:

expansion of the programs of central research organisations, by increased research co-operation between industry and government agencies and by the provision of advance grants for selected projects under the Industrial Research and Development Grants Act 1967-73;

continuing liaison between industry, government and other research bodies to ensure that research is directed into commercially viable areas;

continuation of research programs on: small-scale seasoning and processing; the benefits of industry integration; the economic size of sawmilling units for various classes of logs; the complete use of wood including wood residues; the development of small-scale pulp mills; the wider use of species currently considered to be unmerchantable; and the scientific and technological aspects of wood of selected species;

provision of additional funds by the forest industries, trade associations and government to support product R&D, particularly the development of building systems and components, better fastening systems, and the use of natural round timber and railway sleepers;

a further conference to be held in 1979.

32.1.3 A Forest Products Research Conference organised by CSIRO Division of Building Research is held every two years. This is widely attended by CSIRO, State forest service and industry representatives. Recommendations are made relating to research needs and programs, and six specialist committees of the Conference help to ensure follow-up and continuing liaison.

32.1.4 There are no international agreements on wood products R&D at government level. CSIRO and some of the State forest services are members of the International Union of Forest Research Organizations which includes wood products research. There is a very active branch of the Institute of Wood Science in Australia and the CSIRO Division of Chemical Technology and all Australian pulp, paper and hardboard companies are members of Appita (the Australian and New Zealand Pulp and Paper Industry Technical Association).

32.1.5 There is both formal and informal research co-operation with New Zealand in some areas. The increasing dependence of the wood products industries of both countries on plantation pines should be noted.

32.2 ORGANISATION OF R&D, AND FUNDING

32.2.1 The overall organisation of wood products R&D in the government sector is shown in Figure 32.1; some of these groups are primarily concerned with forestry R&D, but do have some interest in wood products R&D. The various bodies involved are:

Australian Forestry Council: State Ministers of Forestry under the chairmanship of the Commonwealth Minister for Primary Industry;

Standing Committee of the Australian Forestry Council: Heads of State forest services, together with Chiefs of CSIRO Divisions of Forest Research, Chemical Technology and Building Research, the last two having observer status only;

Joint Council of Forest Industries: representatives of the Standing Committee of the Forestry Council and industry, together with the Chief of the CSIRO Division of Building Research;

Research Working Groups of the Standing Committee: at present there are 11 groups all dealing with forestry topics and each consisting of specialists chosen from CSIRO, State forest services and industry. Five wood products research groups were recommended to the Standing Committee by the 1977 Forest Products Research Conference, and there are now plans to establish two of these, to be concerned with seasoning, and with preservation, of timber;

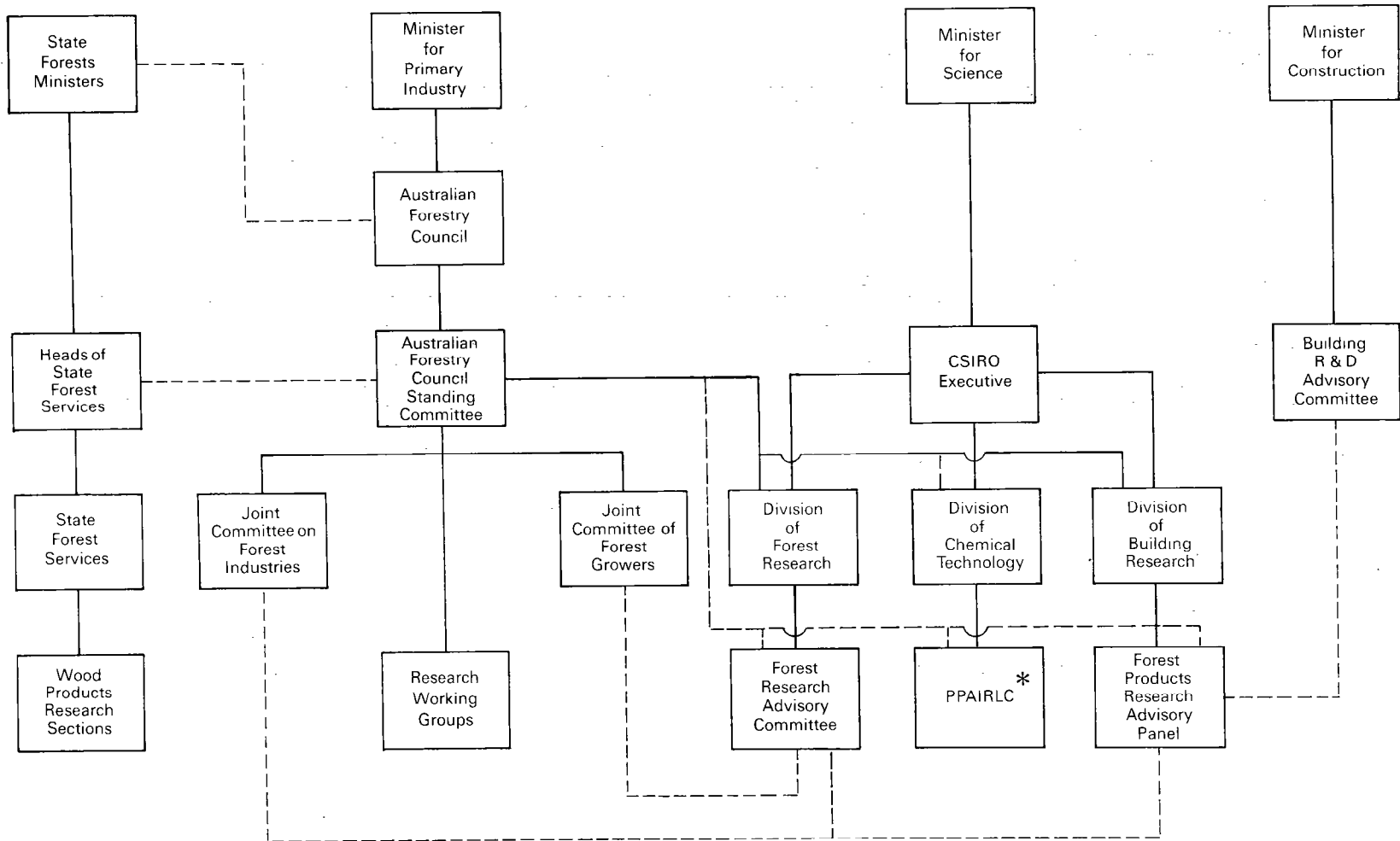
Building Research and Development Advisory Committee (BRDAC): members from CSIRO, government departments, industry and universities. This Committee advises the Commonwealth Minister for Construction;

Forest Products Research Advisory Panel: representatives of BRDAC, industry associations (timber producers, plywood, particleboard, sawmillers, timber preservers), NSW Forest Commission Wood Technology Division, CSIRO Division of Building Research. This panel acts as an advisory committee to the CSIRO Division of Building Research;

Pulp, Paper and Allied Industries Research Liaison Committee (PPAIRLC): representatives of Joint Council of Forest Industries, industry (pulp, paper, hardboard), CSIRO Head Office and Division of Chemical Technology. This Committee acts as an advisory committee to the CSIRO Division of Chemical Technology.

32.2.2 For the year 1976-77, the funds spent on wood products R&D amounted to about \$8million, and their source and distribution are summarised in Table 32.1 which is based on the data given in Section 32.3. This table shows that government sources provided 59% of the total funds for R&D, and that government laboratories spent 53% of the total funds, tertiary institutions 4% and industry 43%.

1977



* PPAIRLC = Pulp, Paper and Allied Industries Research Liaison Committee

TABLE 32.1
EXPENDITURE ON WOOD PRODUCTS RESEARCH 1976-77
\$million

Source of Funds	CSIRO	State Forest Services	Tertiary Education Institutions	Industry and Industry Associations	Total
Cwlth Govt.	3.02	-	0.16	0.32(a)	3.50(b)
State Govts.	-	1.12	0.10	0.02	1.24
Industry	0.04	-	0.05	3.11	3.20
Other	0.05	-	-	-	0.05
Total	3.11	1.12	0.31	3.45	7.99

(a) IR&D Incentives Board grants paid in 1976-77.

(b) Includes \$20,000 for R&D done at the National Materials Handling Bureau.

32.3 DESCRIPTION OF MAJOR R&D ESTABLISHMENTS

COMMONWEALTH GOVERNMENT

32.3.1 CSIRO Division of Building Research (CSIRO-DBR). The expenditure for research on wood products by this Division in 1976-77 was \$1.9million, about 40% of the expenditure for the whole Division. The staff concerned in this research numbered 74 of whom 32 were professionally qualified. The sections concerned with wood products research are Conservation and Biodegradation, Forest Conversion and parts of the Structures and Materials Science sections. Industry gave \$25,000 to support this research.

32.3.2 CSIRO Division of Chemical Technology (CSIRO-DCT). In 1976-77 this Division spent \$893,000 of Treasury funds on research into wood products; this was about 41% of total expenditure of such funds by the Division. Other funds received in the year for wood products research came from Department of Foreign Affairs \$116,000, Commonwealth Fund for Technical Co-operation \$48,000, and industry \$9,800. Thirty eight staff members, of whom 24 were professionally-qualified, were engaged in this research. The broad research programs include cellulose resources, lignin technology, agro-industrial systems, water and waste water purification and biosynthetic technology. The first three of these, and sections of the last three, are concerned with wood products.

32.3.3 The CSIRO Divisions of Forest Research, Entomology, Land Resources Management, Land Use Research, Mechanical Engineering, Plant Industry and Soils are also active to varying extents in fields which are of interest to the wood products industry. The Packaging Centre, National Materials Handling Bureau, Department of Productivity does some work on the development of improved evaluation methods for wooden and paperboard containers, the cost of which was \$19,500 in 1976-77.

STATE GOVERNMENTS

32.3.4 Forestry Commission of NSW, Wood Technology and Forest Research Division (FC-NSW). Expenditure for 1976-77 on wood products research by this body was \$540,000, and the work required 13 professional and 25 other staff. Four groups, Biology, Building and Engineering, Chemistry and Forest Conversion Engineering are engaged in this research.

32.3.5 Department of Forestry, Queensland, Timber Utilization Branch (DFQ). The Branch has three sections concerned with wood products research: Timber Conversion, Seasoning and Mechanics; Wood Structure and Utilization; and Wood Chemistry and Preservation. There were 40 staff of whom 12 were professionally-qualified. The relevant expenditure for 1976-77 was about \$490,000.

32.3.6 Woods and Forests Department, South Australia (WFD-SA). Some wood products research is carried out at the Mount Gambier State Saw Mill, mainly on the recovery of sawn and milled Pinus radiata. The cost of this research in 1976-77 was \$12,300.

32.3.7 Forest Department, Western Australia (FD-WA). The Department engages in wood products research infrequently, but is developing an experimental high-temperature kiln for rapidly-grown young Pinus radiata. Cost of this project has been \$150,000, over eighteen months, say \$75,000 in 1976-77.

32.3.8 No other State forest department reported activity in wood products research for 1976-77.

TERTIARY EDUCATION INSTITUTIONS

32.3.9 The Australian National University Department of Forestry, and the University of Melbourne Department of Agriculture and Forestry, carry out some research on wood products. Four postgraduate projects at ANU are relevant: relationships between eucalypt growth, wood structure and pulp properties; structure of Indonesian hardwoods; marine durability of eucalypts; stress grading of pine in relation to growth characteristics; and two at Melbourne: high temperature seasoning of Pinus radiata, and the use of incision and compression to assist preservative penetration. In all cases the research is jointly supervised by a research scientist from CSIRO-DBR. The annual cost of this work is estimated to be \$90,000.

32.3.10 In the University of Melbourne Department of Chemistry a three year postdoctoral research fellowship in colloid science related to paper-making was completed in 1976-77. Australian Paper Manufacturers Ltd contributed \$10,000 per annum to this. In 1976-77, a three year program to investigate the microbiology of soft rot was started at the University of Queensland Department of Microbiology, with a grant of \$20,000 per annum from the State Electricity Commission of Queensland in collaboration with timber preservation companies in Queensland and Northern NSW.

32.3.11 Research projects dealing with the mechanical properties of plywood and plywood structures were undertaken at the request of the Plywood Association of Australia at Capricornia Institute of Advanced Education, Rockhampton, Preston Institute of Technology and Swinburne College of Technology, Melbourne. Several short-term and confidential projects are also known to have been carried out by universities and Colleges of Advanced Education on behalf of industry during 1976-77.

INDUSTRY

32.3.12 Associated Pulp and Paper Mills Ltd (APPM) produces printing, writing, magazine and fine papers and has mills at Burnie and Wesleyvale, Tasmania; Shoalhaven, NSW; and Ballarat, Victoria. Its Research Division is at Burnie. A subsidiary company, Burnie Board and Timber Pty Ltd, produces particleboard and timber at Wesleyvale, Tasmania.

32.3.13 Australian Newsprint Mills Ltd (ANM) operates a Research Division at its mill in Boyer, Tasmania. The major research programs are concerned with mechanical pulping and with environment protection, both in relation to its existing mill and to its proposed mill near Albury, NSW.

3.3.14 Australian Paper Manufacturers Ltd (APM) produces packaging and industrial papers and paperboards. It has mills in Maryvale, Fairfield and Broadford, Victoria; Botany, NSW; Petrie, Queensland; Port Huon, Tasmania; Millicent, SA; and Spearwood, WA. Subsidiary companies in the wood products field are APM Wood Products Pty Ltd, which manufactures softwood and hardwood products including kiln dried timber, roof trusses and wall frames; Integrated Forest Products Pty Ltd, which uses pines from ACT plantations to manufacture plywood and sawn timber; and APM Fibrecraft Pty Ltd, Preston, Victoria, which makes moulded pulp products. APM's Research Division is at Alphington, Victoria, with a Packaging Engineering Section at its Melbourne head office.

32.3.15 Bowater-Scott Ltd makes sanitary papers and tissues at Box Hill, Victoria, and mechanical pulp and sawn timber from pines at Myrtleford, Victoria. Bunning Bros Pty Ltd are sawmillers and producers of timber products in Western Australia. Hardboards Australia Ltd is owned 50% by APPM and 50% by CSR Ltd, and makes hardboards and related products at Raymond Terrace, NSW; Burnie, Tasmania; Ipswich, Queensland; and Bacchus Marsh, Victoria. Kimberly-Clark of Australia Pty Ltd makes sanitary papers and tissues at Millicent, SA and has a converting operation in Sydney. Pyneboard Pty Ltd is owned by CSR Ltd, and manufactures

particleboard from Pinus radiata at Tumut and Oberon, NSW; and at Rosedale, Victoria.

32.3.16 Smorgon Consolidated Industries Pty Ltd is a diversified company which manufactures wood pulp and industrial papers and paperboards at Brooklyn, Victoria. Softwood Holdings Ltd produces timber products and particleboard in South Australia and Victoria. A.V. Wehl Industries Ltd, in which Australian Consolidated Industries Ltd has a major shareholding, is involved in the manufacture of particleboard at Ballarat, Victoria, and laminated paper products at Cheltenham, Victoria. Woodland Ltd is based in Brisbane, and manufactures particleboard and timber products.

32.3.17 In 1976-77 these companies employed a total of 151 research staff, of whom 71 were professionally-qualified, and their expenditure on R&D totalled \$2.95million. Several other companies engaged in R&D to a relatively minor extent have not been included in this survey. A very wide range of research projects was undertaken, with major programs in the following areas:

- . relationships between tree growth, wood properties, and pulp quality for pines and eucalypts;
- . improvements in mechanical pulping, especially in relation to newsprint and printing papers;
- . improvements in chemical pulping and associated recovery systems;
- . utilisation of wood wastes and recycled fibres;
- . improved methods for forming paper and paperboard, including dry forming;
- . optimisation of design of fibreboard containers;
- . improvement of particleboard properties, and the development of grades for water-proof flooring;
- . drying of hardwoods and softwoods;
- . pollution control and noise abatement in pulp, hardboard, and particleboard manufacture.

INDUSTRY ASSOCIATIONS

32.3.18 Australian Particleboard Manufacturers Association (APMA). This organisation has been providing funds (in 1976-77 \$10,000 per annum) to the CSIRO Division of Building Research (CSIRO-DBR) for particleboard research in the areas of non-destructive testing, behaviour of flooring under adverse weather conditions, protection from mould and decay, pine-tannin adhesives, development of criteria for structural use (including fastenings), control of formaldehyde emission and fire retardancy.

32.3.19 Plywood Association of Australia (PAA). A total of \$12,000 was spent on R&D in 1976-77, to sponsor research on plywood structures at a number of colleges of advanced education. PAA also carried out work itself on the development of a stress-grading machine for plywood.

32.3.20 Radiata Pine Association of Australia (RPAA). This group carries out some R&D itself as well as sponsoring it elsewhere. One professional is engaged about full time on R&D. Current projects are: surface treatments for Pinus radiata flooring to protect it from weather damage during house construction by the 'platform' method (which the RPAA is undertaking itself); high temperature seasoning of Pinus radiata under restraint (with Softwood Holdings Pty Ltd and CSIRO-DBR); and the development of proof testing of wood (with CSIRO-DBR and WFD-SA). Funds spent on research in 1976-77 amounted to \$60,000.

32.3.21 Tasmanian Timber Promotion Board (TTPB). This board has two professional staff on R&D activities, one of whom is working on seasoning research at CSIRO-DBR. Other projects are; hardwood preservative treatments for external use, the development of new timber foundation systems to compete with concrete slabs, and the optimization of systems for framing timber houses. The cost of R&D for 1976-77 was \$25,000 of which \$9,000 was received from the Tasmanian Government.

32.3.22 Victorian Timber Promotion Council. In 1976-77 this organisation engaged in R&D related to timber structures, flooring systems, proof testing and the use of laminated timber. The cost was \$70,000 of which \$7,000 was obtained from the Victorian Government and the balance from the sawmilling industry.

32.4 DESCRIPTION OF MAJOR R&D PROGRAMS

(In this section the number of professional research staff engaged in a particular program is indicated by a figure in parenthesis).

Basic wood science

32.4.1 CSIRO Division of Building Research (CSIRO-DBR) has programs on wood anatomy and wood chemistry to provide information to assist in utilisation and resource improvement, particularly for rapidly-grown eucalypts and pines (2). CSIRO Division of Chemical Technology (CSIRO-DCT) has basic research programs in wood polysaccharide structure (2) and the interaction between fibre and water (1). Basic studies in wood anatomy are undertaken at the Forestry Commission of NSW (FC-NSW) in relation to timber identification and the effect of silvicultural conditions on wood properties (2), and also at the Department of Forestry, Queensland (DFQ) (2).

Sawmilling

32.4.2 Growth stress presents a problem in the sawmilling of the smaller, rapidly-grown trees now becoming an increasingly important part of the forest resource. CSIRO-DBR is studying the relationships between log characteristics, sawing methods and machinery, and product recovery, to improve sawmill efficiency, particularly for regrowth Eucalyptus regnans and Pinus radiata (2.5). They are also working to improve the work environment through noise, hazard and stress reduction (3). Softwood Holdings Ltd is also active in research on the reduction of noise in sawmills. The optimisation of the sharpening and hardening of bandsaws for Pinus radiata and hardwoods, particularly Brush Box which has a high silica content, has been successfully studied by FC-NSW (1).

Preservation

32.4.3 Wood preservation has been an important and successful research area in Australia for many years. CSIRO-DBR (12) is studying the biology and mode of action of wood-destroying organisms, the detection of biodegradation and the development of preservatives and preservation techniques, particularly those which minimise health and environmental hazards. Some specific problems being investigated are: soft rot in poles treated with Copper-Chrom-Arsenic (CCA), which now appears to be a major problem in Queensland and northern NSW; penetration difficulties with Pinus radiata heartwood and dense hardwoods; and preservation and fire retardant treatments for panel products. The timber preservation industry in Queensland and northern NSW is currently providing \$15,000 per year for three years to assist with the soft rot program. The CSIRO Division of Entomology is also active in preservation research in relation to termites (2). Soft rot in CCA-treated poles is also being tackled by FC-NSW (1), DFQ, and the University of Queensland where funds have been provided by the timber preserving industry and the Queensland State Electricity Commission.

32.4.4 The development of treatments for woods where conventional methods are unsuitable, such as pine heartwood and dense hardwoods, is being studied by FC-NSW (1) and DFQ. Treatments for protection from marine borers are being investigated by DFQ and CSIRO-DBR. DFQ is also studying the preservation of mining timbers and the development of some novel preservation systems. It has six professionals working in wood preservation R&D.

32.4.5 Almost all the R&D on protective finishes for wood is done by the paint industry which is estimated to be spending about \$1.6million annually on it, equivalent to about 50 professional staff. However, this R&D is regarded as outside the scope of this Chapter. Some research on finishes is done by FC-NSW (1) with emphasis on how to treat the wood before applying the finish. The work of the Radiata Pine Association of Australia on surface treatments for Pinus radiata flooring is mentioned in 32.3.16.

Seasoning

32.4.6 Australia is probably leading the world in high-temperature seasoning and has pioneered the high-temperature drying of pine under restraint to prevent twist. High temperatures are now used in many Australian plants and a continuous, high-temperature kiln is under construction following successful experimental development by CSIRO-DBR.

32.4.7 CSIRO-DBR's seasoning program (2.5) is aimed at improved understanding and efficiency of seasoning for both hardwoods and softwoods, and at finding ways of overcoming checking and collapse in regrowth Eucalyptus regnans. Collaboration is maintained with the Radiata Pine Association of Australia and the Tasmanian Timber Promotion Board; the latter provides some funds and a research officer to carry out a project on the use of ultrasonics to prevent collapse of Eucalyptus regnans during seasoning.

32.4.8 High-temperature seasoning of plantation pines and cypress pine is also being investigated by DFQ, along with studies to improve drying schedules for dense hardwoods when atmospheres of high humidity are used (1). FC-NSW is studying the optimisation of sawing, steaming and kiln-drying schedules in the seasoning of hardwoods, and juvenile pine including peeler cores (1). The Forests Department, Western Australia (FD-WA) is building an experimental, high-temperature kiln for young Pinus radiata using a ferrocement process.

Quality testing

32.4.9 Australia is well-advanced in understanding the mechanical requirements of structural timbers and in their specification. FC-NSW has developed a 'Computermatic' stress grading machine which measures the bending stiffness of a piece of timber non-destructively along its length. Eighteen units are in use in Australia and 60 have been sold overseas. FC-NSW is continuing with studies of the use of the machine for green hardwoods and cypress pine, and particularly for the derivation of basic working stresses from stress grades (1.5). CSIRO-DBR on the other hand is working on a 'proof grading' system. In this each piece of timber to be graded is subjected to a pre-determined load calculated from the load it is required to withstand in use. This system is claimed to give a better guarantee of performance than 'stress grading' and the equipment required is cheaper (2).

Plywood, veneers and other laminated products

32.4.10 CSIRO-DBR is doing basic work on wood adhesion, the hygroscopic properties of plywoods, and wood-glue interaction, including the problems presented by some woods with a high content of extractives and high densities, and by veneers impregnated with preservatives. The optimisation of log selection for plywood manufacture is being studied, and a range of local woods is being evaluated for plywood suitability. Techniques for peeling thick veneers and using them in structural laminates to improve log utilisation have been studied, but these studies have now been suspended because of lack of staff. Computer modelling is being used for improving the efficiency of plywood mills (4).

32.4.11 The development of improved glueing technology for laminated beams is being studied by FC-NSW (1) and DFQ has a program of evaluation and development of laminated building members using solid timbers, veneers and particleboard (1).

32.4.12 The mechanical properties of various plywood structures have been investigated for the Plywood Association of Australia in sponsored research and the Association itself is developing a stress grading machine for plywood. FC-NSW is evaluating the long-term performance of particleboard and plywood as sheet flooring materials (1).

Particleboards

32.4.13 The development of a particleboard suitable for exposure to the weather in 'platform' housing construction has been a notable achievement by the industry and a local chemical company which developed the resin required. CSIRO-DBR (2), Pyneboard Pty Ltd (1), Softwood Holdings Ltd, and FC-NSW (1) are continuing work in this area and CSIRO-DBR is also working on the use of particleboard as a structural material and the development of fungicidal, termiticidal and fire-proofing treatments. Pyneboard Pty Ltd is investigating the control of hygroexpansivity and warp and the development of improved particleboard laminates (3).

Hardboards and insulating boards

32.4.14 Hardboards Australia Ltd is undertaking applied research on the optimisation of resource utilisation and process conditions, new product development, including reduction of fire hazards, and process changes to meet environmental requirements (4). Burnie Board Pty Ltd, a subsidiary, is studying the possible use of eucalypt bark in hardboards.

Furniture

32.4.15 There appears to be little research on furniture, although the Prahran Institute of Technology, in collaboration with CSIRO-DBR, is developing a simple mechanical testing rig for chairs and other furniture components as a first step in setting Australian standards.

Wood residues and by-products

32.4.16 CSIRO-DBR has a continuing program to develop the use of tannins from the bark of Pinus radiata in waterproof adhesives for plywood, particleboard and timber laminates (3). It is collaborating with the particleboard industry. Associated Pulp and Paper Mills Ltd (APPM) and Australian Paper Manufactures Ltd (APM) are also active in this field.

32.4.17 Studies aimed at developing the use of pine bark in horticulture are being carried out by FC-NSW, Softwood Holdings Ltd and APM. APPM is working on the briquetting of eucalypt bark for fuel. NSW-FC is continuing work on the use of eucalypt sawdust in horticulture (1).

32.4.18 CSIRO-DBR is studying the use of sawdust in lightweight, clay building bricks and in sound-absorbing, resin-bonded tiles. They have also developed a fluidised-bed sawdust combustor to produce heat that can

be used, for example, in kiln drying. Sawdust can also be used to produce charcoal and CSIRO-DBR is using this both as an extender for oil fuel and in charcoal-cement bricks (2).

32.4.19 CSIRO-DCT is developing the use of wood fibre additions to concrete to improve the modulus of rupture and to reduce shrinkage cracking (1). As a means of utilising trees too small for conventional processing, this Division is also developing a resin-bonded composite made from oriented strands of crushed tree stems; this can be formed into a variety of sections and used as a substitute for solid timber (1).

32.4.20 The use of 'Paraquat' to stimulate the production of resin in pines is being studied by CSIRO-DCT (2) and the QFD is examining the properties of the timber from trees which have been so treated. CSIRO-DCT is also in the early stages of a study of the use of cellulosic wastes to produce fuels and organic chemicals by microbiological processes (1).

Pulp

32.4.21 The assessment of pulpwood quality is an important research interface between forestry and wood products. CSIRO-DCT collaborates with state forest services in the assessment of resources and is also studying native hardwoods from Sarawak as part of a Colombo Plan Aid Program (3). APM has programs to assess the effects of age, fertilisation and other growth variables on the pulpwood quality of Pinus radiata and plantation eucalypts in Victoria (1). The control of deterioration in chip piles is being studied by APPM.

32.4.22 Mechanical pulps can be produced in very high yield at relatively low capital cost per tonne and on a small scale. Australian Newsprint Mills Ltd (ANM) is studying Pinus radiata thermomechanical (TMP) and chemi-thermomechanical (CTMP) pulping as a means for reducing its present imports of long fibre chemical pulp and also as the basis for a projected new mill in NSW (6). APPM is investigating optimisation in the application of TMP to pine woods for making magazine papers, and CSIRO-DCT is studying the application of both TMP and CTMP to eucalypt wood. The latter organisation is also investigating the separation of fibres in chemically treated wood chips by explosion rather than mechanical attrition, with the objects of lowering energy consumption in pulp manufacture and reducing the capital cost per tonne (4).

32.4.23 New, environmentally acceptable, methods of chemical pulping suitable for making strong pine pulps economically on a scale appropriate to Australian conditions are being sought by APPM, APM and CSIRO-DCT. APPM has been concentrating on soda-oxygen pulping but recently has also started R&D on the soda-additive pulping. APM (5) is developing a soda-anthraquinone process which it discovered recently simultaneously with companies in Canada and Japan. This should prove to be a major advance in chemical pulping technology. CSIRO-DCT has been studying the use of ethanolamines to make strong chemical pulp, and to produce, simultaneously, useful by-products from lignin (4). APPM and APM are both active in R&D dealing with the recovery of reagents from sulphur-free, alkaline pulping systems.

32.4.24 Research to reduce effluents and pollutants is in progress in all pulp companies. ANM is developing technology for the treatment of TMP pine effluent (2). CSIRO-DCT has developed new adsorption and ion-exchange technology in its water and wastewater programs and their application to pulp and paper effluents is being studied (1). They are also endeavouring to develop an instrumental method for monitoring biological oxygen demand (1). APM (1) and APPM are investigating the optimisation of the processes for bleaching of eucalypt pulp, including effluent quality.

32.4.25 CSIRO-DCT is investigating the integrated production of paper pulp, protein and other products from the complete utilisation of crops such as kenaf and sugar cane.

Paper and paperboards

32.4.26 APM is continuing a long-term program to improve methods of manufacturing multi-ply paperboard when using furnishes with a high content of recycled fibre (3); a new forming process has been developed in collaboration with an overseas company. APM is also engaged in a collaborative research program on the development of the dry forming process for paperboard. The company maintains programs to establish better understanding of the requirements and properties of paperboard container materials and the development of improved products and manufacturing methods (2).

32.4.27 APPM has current programs concerned with the development of magazine papers, computer paper and electrostatic copying paper, as well as a study to improve the assessment of the printing quality of paper (2).

32.4.28 CSIRO-DCT, in collaboration with an Australian paper company, is exploring the application of its explosive pulping method (see 32.4.22) to the disintegration of, and separation of impurities from, wastepaper. It has also developed a process for applying starch and pigments between the plies of a multi-ply paperboard as an alternative to conventional methods.

Paper and paperboard products

32.4.29 APM has a laboratory and engineering group which carry out R&D on package design and optimisation of packaging methods. CSIRO-DCT is developing paper-plastic composite materials for a range of uses, including containment of wool bales (2). Some years ago CSIRO-DCT, with the aid of industry funds, operated a research program on container-making. Consequently, it still provides assistance to a local equipment manufacturing company which is producing a new type of waxing machine for corrugated containers.

32.4.30 Development work is also carried out by some companies on paper and paperboard conversion but this is generally of a very applied nature and related to the adaptation of known technology to local raw materials and market needs. Considerable assistance is generally provided by suppliers of the materials used, adhesives, resins, film for laminating, etc.

Printing

32.4.31 No research appears to be done by the printing industry or by government authorities for this industry. The technical work done is largely that of adaptation and trouble-shooting, with assistance from suppliers of paper, ink and printing plates. The Australian Magazine Publishers' Association is currently considering the establishment of a central technical organisation. This may eventually lead to some research in the industry.

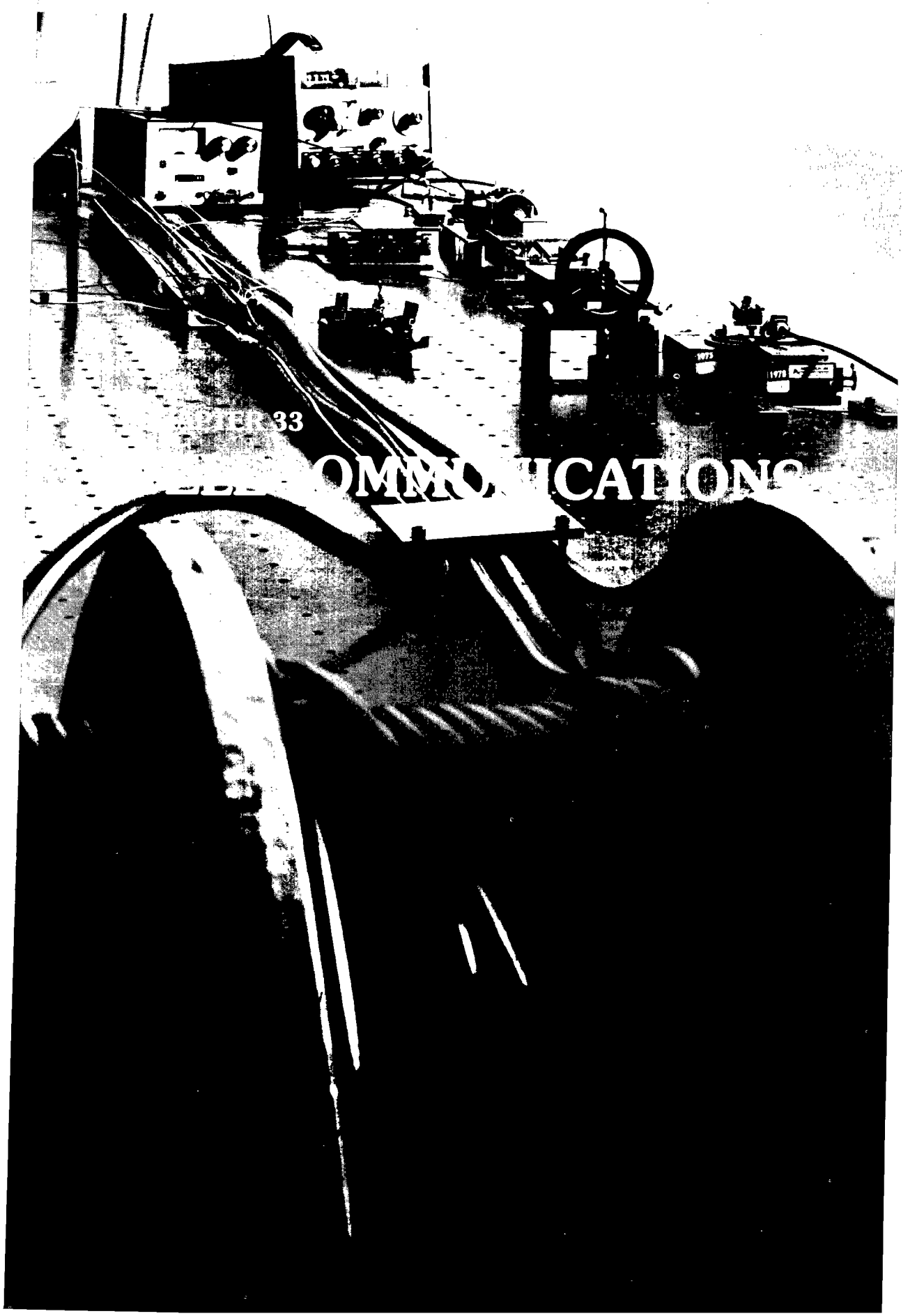
Summary

The overall distribution of R&D activity is shown in Table 32.2

TABLE 32.2

OVERALL DISTRIBUTION OF R&D ACTIVITY - 1976-77

	<u>No. of professional research workers engaged</u>
Basic wood science	10
Sawmilling	8
Preservation	26
Seasoning	7
Quality testing	7
Plywoods, veneers and other laminated wood products	7
Particleboards	10
Hardboards and insulating boards	4
Furniture	-
Wood residues, by-product and miscellaneous uses	15
Pulp	41
Paper and paperboard	12
Paper and paperboard products	14
Printing	-
	161



CHAPTER 33

COMMUNICATIONS

Photograph: Drum lengths of experimental optical fibre cable undergoing transmission characterisation in Telecom Australia's research laboratories.

(Photograph courtesy Telecom Australia Research Laboratories)

CHAPTER 33

TELECOMMUNICATIONS

33.1 INTRODUCTION

33.1.1 This chapter covers R&D activities performed in Australia which have their prime outlet in the provision of telecommunications services. The telecommunications services covered by this report are:

- . telephone services,
- . telegraph and telex services,
- . record and data transmission services,
- . radio and television program relay services,
- . radio and television broadcasting services.

Other smaller-scale telecommunications services include:

- . mobile radio services
- . ship-to-shore and outpost radio services
- . ground-to-air communications services and navigational aids.

Some degree of overlap occurs with material covered in Chapter 27, Electronics and Chapter 34, Scientific and Technical Computing.

33.2 ORGANISATION, POLICIES AND FUNDING

COMMONWEALTH GOVERNMENT

33.2.1 The importance to society of telecommunications services and their impact at national and international levels are such that their distribution, development and operation in Australia is regulated by legislation administered by Commonwealth Government departments and agencies. Government bodies are also major operators of specific types of service. These agencies are therefore deeply involved with the science and technology of telecommunications, which is directly relevant to the fulfilment of their responsibilities.

33.2.2 Commonwealth Government bodies with responsibilities primarily directed at the regulation or provision of telecommunications services are:

- . Responsible to the Minister for Post and Telecommunications
 - Postal and Telecommunications Department
 - Australian Telecommunications Commission (Telecom Australia)

Overseas Telecommunications Commission (Australia)
Australian Broadcasting Commission
Australian Broadcasting Tribunal.

Responsible to the Minister for Defence
Department of Defence, and the Armed Forces

Responsible to the Minister for Transport
Department of Transport.

33.2.3 It is worth noting that, following recent Government-initiated inquiries, Commonwealth legislation affecting radio and television broadcasting in Australia is being, or recently has been, examined and amended. There is also an independent inquiry into whether Australia should have a national communications satellite. The outcome of these inquiries, etc, will have a significant effect on the future directions of telecommunications in Australia.

INDUSTRY

33.2.4 The major determinant of the characteristics of the Australian telecommunications industry is its relationship with its major customer, the Commonwealth Government. The Commonwealth Government agencies operating telecommunications services do not manufacture their own equipment but procure most of it from Australian industry by competitive tender and contract processes. They are involved in research and development with the principal object of establishing their own independent competence to determine and specify the technical facilities and performance of equipment for which they invite tenders worldwide. In this sense, these Commonwealth Government agencies, which provide almost all of the market for telecommunications equipment in Australia, influence the choice of technology to be provided in the equipment which they buy.

33.2.5 The Australian telecommunications industry has developed significantly since World War II, to the point where it can provide the major equipment needs of these agencies. However, the industry is very dependent on the purchases of these agencies for its continuing economic viability and its development has largely been founded on this market.

33.2.6 By virtue of its responsibilities and the large scale of its operations, Telecom Australia alone provides a significant market and, therefore, a significant influence on the Australian telecommunications industry. In 1974-75, Telecom Australia purchased over 90% of its total equipment requirements from Australian industry, this representing about 75% of the total output of local industry. By virtue of its responsibilities to the Australian Broadcasting Commission (ABC) for the technical performance, specification and operation of the ABC's transmitters, it influences the market for large radio and TV broadcast transmitters. This latter market is also influenced strongly by the Postal and Telecommunications (P&T) Department through its regulatory responsibilities with respect to the technical performance of all radio and television transmitting equipment in Australia. The P&T Department's influence also extends into the market for all radio transmitting equipment (transceivers, etc) by virtue of these responsibilities.

33.2.7 Before 1 July 1975, the present functions of the P&T Department and Telecom Australia were combined in the then Postmaster-Generals' (PMG's) Department, and the PMG's Department be said to have had an even greater influence on the development of the Australian telecommunications industry than does Telecom Australia now. The PMG's Department exercised its influence in two ways - by its procurement practices and through its research and development.

33.2.8 In procuring its needs the Department, although calling worldwide tenders, favoured the selection of local products by notionally adding tariffs in its tender price evaluations. This enabled Australian industry to compete with a 'tariff advantage'. Similarly, for logistic reasons the Department was motivated to obtain its major equipment items locally, as long as the local industry was competitive. Through its procurements it therefore promoted the establishment of local industry, which often manufactured under licence to overseas industry, for the production of major items such as switching equipment for exchanges, telephones and telecommunications cables.

33.2.9 In specifying the technical performance of successive generations of these and other major items, the Department was guided by its own research and development activities. In turn, through its procurement practices it influenced Australian industry to develop and adopt these new technologies.

33.2.10 The 31 major companies manufacturing telecommunications equipment in Australia are members of the Australian Telecommunications Development Association (ATDA), an industry association which represents the view of this industry sector to Government. The following general conclusions can be drawn regarding the Australian telecommunications industry:

- The concentration of most production among six equipment manufacturers (Amalgamated Wireless (Australasia) Pty Ltd, L.M. Ericsson Pty Ltd, the Philips group of companies, Plessey Australia Pty Ltd, Siemens Industries Ltd, and Standard Telephones and Cables Pty Ltd) and four cable manufacturers (Austral Standard Cables Pty Ltd, Olex Cables Ltd, Conqueror Cables Ltd, and Pirelli Cables Australia Ltd) is indicative of the world trend to concentration of production into about twelve major multinational companies.

- The over-riding proportion of Australian companies which are wholly or partly owned by overseas multinational parent companies is attributable to the (later) development of the Australian telecommunications industry since World War II, during which period overseas companies, initially servicing the markets of their own countries, have become multinational, and company mergers have led to the above-mentioned world-wide trend towards concentration of ownership and production.

- The present overall low level of exports by Australian companies suggests that, under the influence of the policies of overseas parent companies and of the Australian economic and

market environment, the Australian telecommunications industry has based its development primarily on the scale of the local market.

The Australian industry is at present using only 70-80% of its production capacity, in conditions where local demand for products is temporarily suppressed (by 10-15%), and the industry is now beginning to look to Asia as an export market for some products.

The current reduction in demand for the products of the Australian telecommunications industry is not only a result of the general economic downturn but also of the change of status, and resultant financial responsibilities, of its major market outlet, Telecom Australia. Since its establishment as a Commission under the Telecommunications Act on 1 July 1975, Telecom Australia has sought to meet its new financial and service obligations with greater economic efficiency, by slowly reducing its equipment stock holdings, by restraining its equipment procurement programs, and by seeking improved utilisation of its existing network investment. However, this is a short-term 'catch-up' phenomenon. The demand for telecommunications services and telecommunications traffic both continue to grow, and the overall long-term picture is one of a sustained growth rate of about 8% per year. Thus the demand for the products of the Australian industry can be expected to increase proportionately in the near future.

The Australian industry has at present the capacity and technological competence to produce most of Australia's telecommunications equipment needs. It is at present doing so in areas where efficiently scaled local markets permit profitability - although overall profitability is marginal at about 10% on funds employed.

The industry is closely in tune with possible future developments in its major market (Telecom Australia) and budgetary as well as technical decisions of Telecom Australia regarding new technology will have a significant impact on future development and change in the industry, and its consequent capacity to meet Australia's equipment needs.

STATE GOVERNMENTS

33.2.11 State Government agencies also operate dedicated 'private' telecommunications networks to provide the communications facilities needed for the performance of their primary responsibilities, such as electrical power generation and distribution, gas pipelines, rail services, police services, fire and other emergency services. The R&D effort serving the operations of State Government agencies is predominantly performed in industry, from which the agencies purchase their telecommunications systems.

PRIVATE OPERATORS

33.2.12 Other operators of private communications systems include business houses and industry. The largest individual users are banks, airline operators and business houses. Their systems are often small in-house telephone systems, which are not connected into the public national network operated by Telecom Australia. In these cases, the systems are generally provided and serviced by the telecommunications industry. Where special terminal equipment is marketed by industry for private sale to such organisations and connection into the Telecom Australia network is desired or required, the equipment must first obtain approval from Telecom Australia. Industrial mobile radio-communications services also form a major category of telecommunications services supplied by industry and distributed widely among industrial operators. The Postal and Telecommunications Department, through its regulatory responsibilities for the radio frequency spectrum, exercises control over the distribution of such services.

TERTIARY EDUCATION INSTITUTIONS

33.2.13 Most of Australia's universities, colleges of advanced education and technical colleges provide the basic post-secondary telecommunications training for professional engineers and scientists (degree qualifications) and technicians (certificate qualification) employed in the Government and private sectors. The universities and colleges of advanced education also train postgraduate students by involving them in R&D projects related to telecommunications, with various institutions tending to specialise in topic areas related to the interests and expertise of academic staff and their particular facilities available for R&D. There is reasonable liaison between these centres of tertiary education and the Government and industry sectors.

FUNDING

33.2.14 Some of the Commonwealth Government agencies listed previously directly fund R&D in industry or tertiary educational institutions. This takes the form of specific R&D contracts and, in industry, of supply contracts for equipment which necessitate some development. Telecom Australia, the Department of Transport and the Department of Defence fund such R&D, although their total annual expenditure on specific R&D contracts is relatively small - less than about \$100,000 - and variable.

33.2.15 The major body specifically funding telecommunications R&D in centres of higher learning is the Radio Research Board (RRB). The RRB derives its funds from the membership donations of its principal members, Telecom Australia, CSIRO, the Overseas Telecommunications Commission (Australia) (OTC (A)) and the Postal and Telecommunications Department. The RRB disbursed approximately \$150,000 in 1976-77 to assist 60 R&D projects in 16 centres of higher learning. Growth in funds made available to the RRB has not kept pace with inflation, and the effective level of

support is now lower than it was 10 years ago. Specific grants of Government funds for R&D in non-Government institutions, predominantly centres of higher learning, are also made by the Australian Research Grants Committee. Out of a total of 1066 grants valued at \$7million in 1976, about \$150,000 was granted for 17 projects involving telecommunications or related technology in 9 Australian universities.

33.2.16 The Australian Industrial Research and Development Incentives Board disbursed funds totalling \$10million in about 1300 grants to all industry sectors in 1974-75. Of this total, grants totalling \$230,000 were made to 13 member companies of the Australian Telecommunications Development Association.

33.2.17 The Industries Assistance Commission (IAC) report [1] and other documents suggest that the overall funding and distribution of telecommunications R&D by sectors of performance for 1972-73 were approximately:

- \$18-20million by Commonwealth Government agencies - of which about 70% was expended by Telecom Australia and only about \$100,000 (about 0.5%) was expended on R&D contracts to industry and higher education sectors in approximately equal parts.

- \$10-12million by private industry - of which about \$1million was recouped from Government funds through contracts, grants or taxation concessions, with specific grants or contracts accounting for about \$400,000. The total R&D expenditure was distributed by products approximately as below:

transmitting and broadcasting equipment	\$3million,
telephone and telegraph equipment	\$6million,
telecommunications cables	\$2million.

- \$4million by centres of higher learning - most of which is funded from Government sources.

33.2.18 Since 1972-73, real R&D expenditure by Commonwealth Government agencies has been maintained about constant, while expenditure by private industry has declined. This is attributable to the general economic downturn in Australia.

INTERNATIONAL INFLUENCES

33.2.19 The International Telecommunications Union (ITU), a United Nations agency, is the principal international body influencing public telecommunications. Through its three subsidiaries, the International Telegraph and Telephone Consultative Committee (CCITT), the International Radio Consultative Committee (CCIR), and the International Frequency Registration Board (IRFB), it recommends, amongst other

matters, performance standards for telecommunications services, systems and equipment. These influence the products of industry. Recommendations are made on the basis of conclusions from studies of particular topics, which draw contributions from operating administrations and the telecommunications industry throughout the world. These contributions are often based on R&D work. Commonwealth Government agencies, and the Australian telecommunications industry, regularly attend ITU meetings and contribute to ITU activities.

33.2.20 Through the OTC(A), Australia has shareholder or signatory status in international organisations which provide and manage the international segments of the world's telecommunications networks. These organisations include the Commonwealth Telecommunications Organisation, the Commonwealth Cable Management Committee, and the International Telecommunications Satellite Organisation (INTELSAT). Australia, through OTC(A), contributes to the cost of these components of the international telecommunications network and participates in their planning and development. Through the OTC(A) membership, Australia also participates in the R&D activities of these organisations and gains access to their results.

33.2.21 In the field of navigational aids, the International Civil Aviation Organisation (ICAO) has a similar influence on services and system standards as does the ITU in the public telecommunications field.

33.2.22 Other international bodies influencing the choice of telecommunications technology are the International Standards Organisation (ISO) and the International Electro-Technical Commission (IEC). These bodies are primarily concerned with technical standards for components and materials, and for associated testing procedures and specifications. Their field of activity extends beyond the telecommunications sphere, but where telecommunication is involved in their activities, they collaborate directly with the ITU and also with national standards organisations. The Standards Association of Australia, drawing expertise for national standardisation in fields relevant to communications and electronics from the aforementioned Commonwealth Government bodies and private industry, contributes significantly to national and international standards activities related to materials, components and electrical measurements relevant to telecommunications.

ORGANISATION

33.2.23 The Government agencies with planning and operational responsibilities for the provision of telecommunications services conduct R&D with the primary objective of developing an independent competence and awareness of new technological advances; they can then plan and specify the systems to be purchased for the development of the networks which provide the services.

33.2.24 The Australian telecommunications industry mainly performs shorter-term, market-oriented 'development', adapting overseas technology to meet the needs and specifications of its dominantly Australian market.

Some exceptions to this generalisation exist, where several companies perform longer term 'applied research' - notably the major companies such as AWA (micro-electronics/optical fibres and devices), L.M. Ericsson (PBX and PABX), Philips (transceivers), Plessey (PAX and PABX).

33.2.25 CSIRO, although Australia's largest government R&D organisation, does not perform telecommunications research as such, but leaves this field to the government agencies with telecommunications responsibilities. However, some of the basic research performed by CSIRO in radiophysics, materials science, electrical measurements, and in other fields, finds application in telecommunications, and CSIRO Divisions provide consultancy services, or perform contract research, for the government agencies when overlaps of interest or application occur.

33.2.26 There is no formal mechanism to integrate or to co-ordinate the R&D activities of the bodies performing R&D within and between sectors of performance. Some co-ordination is achieved by informal liaison resulting from a general awareness of the responsibilities, activities, expertise and facilities of individual R&D 'houses' in the telecommunications sector. This awareness is established through commercial operations, publications, peer-group associations, seminars, the histories of previous collaboration, and from pressures on resources and research facilities. The relatively small amount of contracted R&D is an indication that some successful collaboration does take place, but other non-quantifiable, cashless collaboration also occurs.

33.2.27 The largest performers of R&D are Telecom Australia and the Australian industry; their efforts dwarf those of the remainder of the field. Telecom Australia has not established the same close R&D relationships with local industry as exist between similar Government telecommunications administrations and industry in some other countries, where up to half the R&D performed by industry is funded through Government contracts. The Australian environment has contributed to this. Telecom Australia has sought to procure the 'best' technology from the world industry for its major network systems, in the realisation that the resources required to develop this technology are large, internationally based and more often resident in overseas parents than with local subsidiary companies.

33.2.28 Telecom Australia, recognising the need to encourage R&D in Australian industry and the industry's R&D potential to perform development-type work more efficiently than Telecom Australia itself can, is now proposing to increase gradually its annual program of R&D contracts with industry in the next few years to a steady level of about \$500,000 per annum. This program will be additional to contracts at present let for the supply of equipment, many of which include a 'design' component (outside the Project SCORE [2] definition of 'R&D'). Notable past examples of this latter type of contract include the development of the 'Type 801' telephone instrument, some developments of Ericsson Crossbar exchange equipment, underground cables, etc. - all of which have called for local adaptive design based on imported technology.

33.3 THE CONDUCT OF R&D

33.3.1 The following remarks outline the R&D activities of various establishments where it is known, since it was not possible in this survey to call for comprehensive information from all establishments.

COMMONWEALTH GOVERNMENT

Telecom Australia

33.3.2 There is an element of R&D in much of the engineering planning and development of Telecom Australia's network, and hence the R&D effort is dispersed throughout the organisation. However, the major R&D activity is centralised in a special Research Department of the Central Administration and the major R&D interactions of this Department occur with the Engineering Department of the Central Administration.

33.3.3 In the year 1976-77 Telecom Australia's total R&D expenditure (including all overheads) was about \$28million. This amounts to 1.4% of total annual expenditure by Telecom, and is comparable with similar broad statistics from overseas administrations.

33.3.4 Half the total R&D expenditure is accounted as labour charges, 25% is other current expenditure and the remaining 25% capital charges (\$4.5million for buildings, and \$1.6million for asset equipment). Total staff directly engaged in the management, conduct, and engineering and administrative support in Telecom Australia's R&D in telecommunications is approximately 233 professionals, 226 technical and 187 others, making a total of 646.

33.3.5 The focal point of Telecom Australia's R&D is the Research Department. The Director (Research) is responsible to the Chief General Manager and controls a total staff of about 500, which includes 130 professional engineers, 30 scientists and 220 technical and artisan staff. The annual costs of operation of the Research Department (excluding 'Commission' overheads) were \$13million in 1976-77 and 90% of the Department's work program was R&D activity.

33.3.6 The Department (known as Telecom Australia Research Laboratories) has the corporate responsibility for maintaining a reference competence in the fields of advanced science and technology relevant to the responsibilities of Telecom Australia and for assisting other (marketing and engineering) Departments of the Commission in the solution of problems requiring the application of this competence. It meets this responsibility through the conduct of selected R&D projects in all fields of telecommunications technology and with application ranging from the long to the short term. The program of work of the Laboratories is reviewed annually in a corporate process known as the Three-Year Program of Research, Development and Innovation. This Program embraces R&D planning and design work performed throughout Telecom Australia which will have an innovative impact on the Telecom network and it provides a corporate mechanism for the co-ordination of this work.

33.3.7 The output of the Laboratories is conveyed to the client Departments of Telecom Australia to assist them with their planning, specification, procurement, installation, operational or maintenance responsibilities.

33.3.8 Major current R&D topics include:

- . optical fibres, devices and transmission systems;
- . digital coding and transmission techniques for voice, data and video signals;
- . high speed data transmission;
- . stored program controlled (SPC) analogue and digital exchange switching systems;
- . audio or video conference services;
- . public automatic mobile telephone service configuration studies;
- . evaluations of new plastics materials for use in telecommunications cable and equipment;
- . failure mechanisms and reliability studies of components and equipment items;
- . processes for the production of specialised and advanced semiconductor devices and device evaluations;
- . processes for the design and fabrication of thick and thin film circuits and microwave striplines;
- . design techniques for and evaluation of microprocessors for control of exchange switching and test equipment; and
- . multipath radio propagation mechanism and rain attenuation at microwave frequencies.

33.3.9 The Research Laboratories of Telecom Australia are a focal point of the R&D contracts let by Telecom Australia. These are let to industry, other government agencies (mainly CSIRO), and to centres of higher learning. The annual level of contracting has fluctuated in accordance with the need and opportunities to let contracts. Over the last three years, contract expenditure has been as in Table 33.1.

TABLE 33.1
TELECOM CONTRACT EXPENDITURE

	<u>1974-75</u>	<u>1975-76</u>	<u>1976-77</u>
To industry	\$12,000	-	\$40,000
To government (CSIRO)	-	-	\$ 5,000
To universities	\$20,000	\$25,000	\$16,000
Total	\$32,000	\$25,000	\$61,000

Overseas Telecommunications Commission (Australia)(OTC(A))

33.3.10 OTC(A) is responsible for the provision and operation of telecommunications services between Australia and overseas countries. This specialised field is characterised by extremely high rates of traffic growth which demand innovation and often involve the special technologies of submarine cable and satellite communications systems. Although OTC(A) does not maintain a specific R&D group, it does undertake in-house R&D and it also contributes to local and overseas R&D establishments to gain access to the technology necessary for its service responsibilities.

33.3.11 In 1976-77 OTC(A) spent about \$800,000 on R&D, comprising about \$300,000 for salaries and salary overheads and \$500,000 for other current and capital expenditures. R&D expenditure was about 1% of total expenditure (\$79million) - a reasonable proportion by international comparison. The full-time equivalents of about three professional and five non-professional staff were engaged on in-house R&D activity or in support of external R&D expenditure - a small number of the total staff of 2100 in both absolute and proportionate terms. Two illustrations of OTC(A)'s financial and technical participation in collaborative international R&D follow:

- In the satellite communications field, OTC(A), a 2.5% shareholder in INTELSAT, participates in the determination of INTELSAT's R&D program, for which the current annual budget is \$6.5 million. Telecom Australia and several Australian companies have won INTELSAT R&D contracts against worldwide competition in the past, but generally Australian companies are not often successful in tendering, despite their competence and interest.

- In the field of submarine cable technology, the Commonwealth Telecommunications Organisation funds R&D through the British Post Office. OTC(A) gains from this R&D, which is oriented towards the specialised materials and components of submarine cables and repeaters. This R&D has yielded royalty revenue from patented vacuum tubes and transistors developed for repeaters.

Postal and Telecommunications Department(P&T)

33.3.12 The P&T Department conducts a limited amount of R&D in the fields relevant to its areas of responsibility, namely, radio and television broadcasting and the management of the radio-frequency spectrum. Total current annual effort is about five man-years.

Department of Defence

33.3.13 The Department of Defence performs telecommunications-oriented R&D in two of its establishments, the Defence Research Centre, Salisbury (DRCS), formerly the Weapons Research Establishment, and the Engineering Development Establishment (EDE). The basic motive of this R&D is the development of expertise and facilities to provide the Defence Services with advice and assistance in matters relating to defence telecommunications. Telecommunications equipment for the Department of Defence is extensively purchased from overseas industry and this in-house R&D is therefore essential to the establishment of independent competence, without industry 'bias', to assist Service personnel to evaluate new overseas equipment, to specify and monitor procurement requirements and, where necessary, to adapt equipment to the Australian environment. It also equips the Defence organisation to participate competently in the Technical Co-operation Program - an arrangement between Canada, the United Kingdom, the United States of America, New Zealand and Australia for the promotion of a regular exchange of technical information in defence R&D, and in other international information-exchange agreements.

33.3.14 The Defence Department spends about \$3million annually (excluding overheads) on its R&D program in this area. The manpower directly engaged in this R&D and the approximate annual R&D capital expenditure, are shown in Table 33.2 for each Establishment for 1976-77.

TABLE 33.2

DEPARTMENT OF DEFENCE RESOURCES FOR R&D IN TELECOMMUNICATIONS

<u>Establishment</u>	Prof.	<u>Manpower</u>			<u>Annual Expenditure(\$million)</u>		
		Tech.	Other	Total	Labour	Capital	Total
Total DRCS	30	37	4	71	\$1.7	\$0.3	\$2.0
Total EDE	20	6	3	29	\$0.8	\$0.2	\$1.0
Total Defence Dept.	50	43	7	100	\$2.5	\$0.5	\$3.0

The approximate percentage distribution of effort by topic areas is research investigations (primarily at DRCS), 77%, and development projects (primarily at EDE), 23%.

33.3.15 Major current R&D projects include:

- . radio propagation studies, HF to UHF;
- . defence fixed message network;
- . defence fixed HF communications systems;
- . defence satellite communications studies;
- . fixed network studies;
- . microprocessor/minicomputer techniques;
- . data link development; and
- . development of field-transportable communications systems.

33.3.16 The Defence Department, through DRCS and EDE, spends a total of about \$0.1million annually on communications R&D conducted externally. This expenditure is predominantly for specific R&D contracts let to private industry in Australia.

Department of Transport

33.3.17 In fulfilling its national transport-oriented responsibilities, the Department of Transport performs R&D in the telecommunications field. This chapter does not report on this special sector of telecommunications R&D; it is discussed in Chapter 35.

INDUSTRY

33.3.18 In the preparation of this chapter, it was not possible to conduct a thorough survey of the R&D activities of the Australian telecommunications industry. Reliance has been placed on the evidence at Industries Assistance Commission (IAC) inquiries [1] as the most authoritative information source available. Of necessity, the data and conclusions drawn from this evidence and quoted below are of a general nature.

33.3.19 The IAC evidence suggests that:

- . R&D activity is concentrated in the ten major companies and in a few of the smaller, specialist companies producing single products;
- . the R&D activity is predominantly of an adapting/modifying and limited development nature, with new technology primarily imported; however, some companies do perform advanced R&D in selected areas. Some examples are: the work on optical devices and fibres performed by Amalgamated Wireless (Australasia) Ltd in collaboration with Telecom Australia; that on jelly-filled

underground pair cables by Austral Standard Cables in conjunction with Telecom Australia; and advanced PBX and PABX development performed by L.M. Ericsson on behalf of the Ericsson international group of companies;

the selection of new technology adopted by Australian industry is most often determined by the procurement specifications of Government telecommunications agencies, notably Telecom Australia, which shop for their equipment requirements and associated technology on the world scene;

at about 7.5% of total sales expenditure, telecommunications R&D expenditure by Australian industry is comparable with that of other developed countries. In absolute terms, however, it is small and parent company policies, the size of the Australian market base, and the high cost of telecommunications R&D in major fields suggest that most major technological developments will continue to be imported into Australia from the overseas parents of the predominantly foreign-owned Australian industry.

TERTIARY EDUCATION INSTITUTIONS

33.3.20 It was not possible in the preparation of this chapter to obtain detailed information about the scientific and technological R&D conducted in the field of telecommunications by Australian centres of higher learning. However, some broad conclusions can be drawn from the lists of projects supported by grants made by the Radio Research Board (RRB) and the Australian Research Grants Committee (ARGC).

33.3.21 General conclusions are that:

- telecommunications-related R&D is conducted in most of Australia's universities and in the major Colleges of Advanced Education in Melbourne, Adelaide and Sydney;

- the R&D is primarily related to the teaching objectives of these institutions and as such is primarily basic research;

- each institution tends to specialise in a particular sector of telecommunications R&D, which is determined by the interest and expertise of a small number of teaching staff and by the facilities (often limited) available for research;

- the bulk of full-time R&D effort is provided by postgraduate students, with part-time participation of, and supervision by, teaching staff, and part-time support by technical staff; some instances of part-time participation by final-year undergraduates are also evident;

- specific R&D grants generally provide funds for equipment (only), and general funds provide for salary expenditures, with almost all funds derived ultimately from government sources;

. the RRB and ARGC receive about 100 applications for specific telecommunications R&D grants annually and disburse about \$300,000 to about 75 projects. Each project typically represents about two man-years of effort per year (one full-time, one aggregated part-time) and hence the total telecommunications-related R&D effort in centres of higher learning amounts to about 200 man-years, or in total expenditure terms (including overheads) to about \$4million per annum;

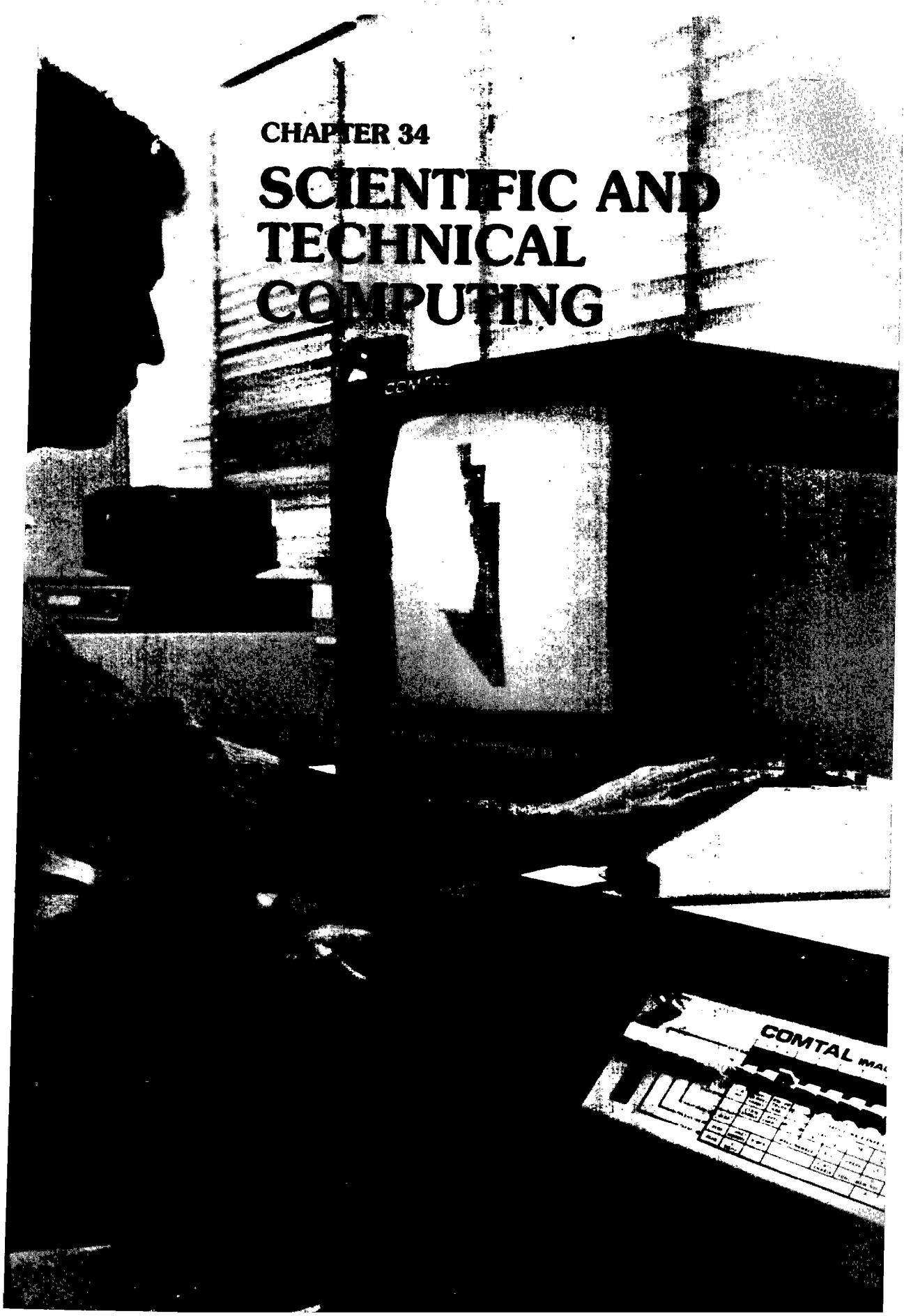
. there is little evidence of any significant contractual R&D relationships between centres of higher learning and the Australian telecommunications industry.

NOTES AND REFERENCES

1. Industries Assistance Commission, 'Telecommunications Equipment', Australian Government Publishing Service, Canberra, 1976.
2. Department of Science, Project SCORE. 'Research and Development in Australia 1973-74'. AGPS, Canberra, 1976.

CHAPTER 34

SCIENTIFIC AND TECHNICAL COMPUTING



Photograph: Use of an interactive digital image processing system for town planning. The town planning package was developed by the National Capital Development Commission, and is operated on the CSIRO's CSIRONET system.

(Photograph courtesy CSIRO Division of Computing Research).

CHAPTER 34
SCIENTIFIC AND TECHNICAL COMPUTING

34.1 INTRODUCTION

DEFINITION OF AREA COVERED

34.1.1 At the outset of this Chapter, it is important to note a number of difficulties which were encountered during its preparation, and which have resulted in a far from complete description of the present state of activity. Information on scientific and technical computing is not always readily available. Few surveys have been made of the area, and examples are known where existing surveys contain incomplete data. This situation arises in part because of the breadth of the area and of its ill-defined boundaries, and in part because there is no overall co-ordination of computing activity within Australia. These inadequacies extend to information on expenditure, manpower, computing R&D and the extent of computer science activity in tertiary education institutions. Further comments on these deficiencies may be found in paragraphs 34.1.8, 34.1.10, 34.3.1, 34.3.2 and 34.3.21.

34.1.2 Computers pervade R&D in all other areas of this volume, and it is difficult (and becoming more so) to separate R&D in scientific and technical computing from R&D in other areas, particularly in Communications and Electronics.

34.1.3 Until recently, discussion of computers has, by custom, generally been restricted to stored-program, digital computers. The advent of electronic devices known as microprocessors, which are as effective as conventional computers in specific applications, has led to a very substantial expansion of the definition of a computer. Many applications (e.g. in the manipulation of digital signals) which previously required complex electronic circuitry are now carried out with microprocessors. This has led to a relaxation of the distinction between computing and telecommunications. This distinction has also recently been further weakened by the increasing use of computers in communications, e.g. computer control of telephone switching, and the greater role for computers being opened up by transmission of digital data. Yet another factor has been the linking together of computers by telecommunications channels, to form resource sharing networks.

34.1.4 Another boundary affected by the advent of the microprocessor is that between computing and electronic engineering. Microprocessors offer the opportunity for an engineer to test his design on a conventional computer, and then to implement it using a microprocessor. The distinction

between computing and electronics thus disappears along with the traditional distinction between hardware and software. For this reason, and because work on computing hardware is described in Chapter 27 (Electronics), the reader is asked to refer to that chapter.

34.1.5 It is convenient and conventional to consider computers in three different categories:

- Large computers (price range \$100,000 to several million dollars), also known as mainframe computers. Such computers are used by many large organisations (but not by small organisations) in both the public and private sectors. Typically, a large computer simultaneously supports a variety of applications, only some of which are relevant to this report.

- Minicomputers (\$4,000 to \$200,000) are sometimes used in the same way as large computers, the only differences being in computing power and price. However, a minicomputer is frequently dedicated to a single application - for example, to the control of an experimental or an industrial process. Minicomputers are extensively used by research workers.

- Microcomputers (\$100 to \$10,000) are a relatively new development, and their impact is only starting to be felt. It is likely that microcomputers will displace minicomputers for some, but not all, applications.

It is also desirable to distinguish between two modes of operation of computers in any of the above categories. One of these modes is the traditional use of computers as 'stand-alone' devices in their own right, i.e. for scientific or technical purposes as large calculating machines. The second mode, which is becoming increasingly important, occurs in the use of 'embedded computer systems', that is, systems and equipment which include one or more computers as components. Examples of such systems are the stored-program telephone exchanges used by Telecom and the Overseas Telecommunications Commission, the TAB on-line betting system, numerous control systems for industrial processes and some laboratory instruments.

34.1.6 Desk and pocket calculators are explicitly excluded from consideration in this chapter. The smaller calculators are more properly considered as 'consumer electronics' rather than computers, and very large calculators may be placed in the microcomputer and minicomputer groups.

34.1.7 Scientific and technical computing for the purposes of this chapter is taken as being 'The Science and Technology of Computing' covering hardware (in parallel with Chapter 27) and systems software (programs devised to make the operation of a computer easier and more efficient, such as compilers and operating systems), and 'computing applied to scientific and technical ends', i.e. scientific applications software such as linear programming and structural engineering packages. It specifically includes 'embedded computer systems' as defined in 34.1.5, although unfortunately this is an area for which very few data are

available. It does not include programs with end uses such as payroll or inventory control. As with the definition of a computer above, there are factors which blur the division between these areas (e.g. the use of technical programs for graphics displays for non-technical ends such as management information systems). In particular, there are computer programs and computer systems, for example data communication software, whose end uses are largely in commercial data processing, but whose development is frequently the responsibility of programmers with a scientific or technical background. In such cases the development effort can be categorised as 'Scientific and Technical Computing', although the programs themselves do not fall into this category. It is also evident that the consideration by this chapter of computing applied to technical ends implies some overlap with most other chapters of this volume.

SIZE OF THE AUSTRALIAN INDUSTRY

Expenditure

34.1.8 In 1974, the most recent year for which figures are available, total expenditure on computing in Australia (excluding data preparation and data control) was \$400million, and was growing at about 20% per year. It could thus have reached about \$700million by 1977. This expenditure can be broadly broken up into hardware 39%, salaries (excluding data preparation personnel) 47%, and software supplies 14% [1]. A survey [2] in 1977 indicated that up to 20% of this expenditure could be classified as scientific or technical computing in the terms used in this chapter, although this should be taken as a maximum upper limit. In another survey [3], usage of 4,100 Australian computers was examined in 1976, and it was found that 11.6% of computers were used in categories which could be classified as scientific and technical computing. It thus appears that expenditure in 1976-77 on scientific and technical computing in Australia might have been anywhere between \$50million and \$140million.

34.1.9 Yet another survey [4] gives the figures shown in Table 34.1 for organisations active in computing in Australia.

TABLE 34.1

USAGE OF COMPUTING IN AUSTRALIA

<u>Area of Application</u>	<u>Percentage of Organisations</u>	
	<u>Private Sector</u> (13,500 surveyed)	<u>Public Sector</u> (109 surveyed)
Business/administration only	48	18
Mainly business/administration	32	47
Equal business/technical	10	22
Mainly technical/scientific	8	9
Technical/scientific only	2	4

The proportion of organisations active in the various areas appears broadly to support the proportions of expenditure quoted in the previous paragraph.

Manpower

34.1.10 Again, only broad figures are available for the manpower resources of the Australian computer industry, but they indicate that about 11,000 were employed as full-time systems and programming staff in the industry in 1975 [4] (total full-time staffing about 45,000), and about 2000 in the Australian computer manufacturing industry in the same year [5]. No figures are available to break down this employment into 'scientific and technical' or 'other'.

International comparison

34.1.11 Table 34.2 shows Australia's position in comparison with some other nations, in 1976 [4]:

TABLE 34.2

NATIONAL USE OF COMPUTERS

	<u>GNP (US\$ billion)</u>	<u>Population (millions)</u>	<u>Installed base number (systems)</u>	<u>Number of systems per million population</u>	<u>Number of computers per \$ billion GNP</u>
United States	1,413.2	211.9	168,800	797	119.4
Japan	450.0	109.7	30,095	274	66.9
Federal Republic of Germany	367.6	62.0	20,860	337	56.7
United Kingdom	173.1	56.2	15,520	276	89.7
France	282.7	52.5	13,064	249	46.2
Australia	72.6	13.3	2,420	182	33.3

34.1.12 Other information on international trade in computers [6] suggests that, for each dollar earned by Australian exports of computers and other office equipment, Australia pays \$13.57 for imports of such equipment. This is far higher than for any other western nation, the next highest being Spain (imports/exports = 5.91), while the ratio for Canada, which is economically the most comparable country, is 1.81. It can be seen that, in comparison with countries of similar GNP per head, the number of Australian installations per head of population, or per billion dollars of GNP, and hence the extent of computerisation, is low.

34.1.13 Almost all computers in Australia are imported, many of them from American-based multinational firms. Unlike the situation in several smaller countries (e.g. Sweden), there is very little local manufacture of computers. Several foreign manufacturers have Australian subsidiaries which are engaged in technical activities in addition to marketing. There is some local manufacture of peripheral equipment, notably computer

terminals, but generally it would appear that hardware production is much lower in Australia than in other economically comparable countries.

34.1.14 The Australian software industry appears to be somewhat more active. There are currently at least 200 data-processing consultants, and 80 computer service bureaux (many of whom also offer consulting services). There are at least three companies with a turnover of about \$4million a year. The figures suggest that, although the software industry is less well developed than in countries like Canada (a country otherwise comparable with Australia), it is firmly established. No data are available to divide software production into 'scientific and technical' and 'other'.

34.2 POLICIES AND FUNDING

POLICIES

34.2.1 There is no arrangement for centralisation of control, co-ordination or funding of the use of computers across all sectors of the Australian economy. Given the diverse usage of computing mentioned above, such centralisation is clearly impractical. There has also been, since 1975, no attempt to provide overall statistical information on numbers and usage of computers in Australia. Prior to 1975 the then Commonwealth Department of Labour and Immigration published a computer census regularly.

34.2.2 Within individual sectors of the economy, however, (government, private enterprise, education, etc.) there are arrangements for the development and implementation of policies regarding computing generally, and, by implication, scientific and technical computing. These, and some related organisational arrangements, are described below.

Commonwealth Government

34.2.3 The Commonwealth Public Service Board, in association with the Inter-departmental Committee on Automatic Data Processing (ADP), is responsible for co-ordination of development and introduction of ADP within the Service. In 1977, the membership of the Inter-departmental committee on ADP was Public Service Board (Chair), Department of Finance, Department of Defence, Department of Social Security and CSIRO. Most Commonwealth statutory bodies are autonomous in their decisions for computer purchase.

34.2.4 CSIRO plays a special role in the provision of services for scientific and technical computing. In 1962, CSIRO was charged by the Commonwealth Government with the responsibility of building up a service based on a central computing unit in Canberra, to be available to

Commonwealth departments and instrumentalities, to State Government departments and instrumentalities, and to universities. This service, called CSIRONET, is operated by the Division of Computing Research, using a Control Data Cyber 76 computer. In 1977-78, the computer was used 35% for CSIRO work, 22% for Commonwealth departments, 4% for State Government departments, and 2% for universities and other approved users. The balance (37%) was used in maintenance of the system.

34.2.5 The recent Independent Inquiry into the CSIRO made a number of policy recommendations relevant to the operation of CSIRONET, and to government computing generally. These included recommendations for the reorganisation of the Division of Computing Research as a computing service network, for charging for CSIRONET services on a cost-recovery basis, and for rationalisation of provision of individual computers in CSIRO Divisions. At the same time, the inquiry recommended that the research effort of CSIRONET should be directly related to user needs, including those of CSIRO, and should be funded by the users. The inquiry also recommended that the Commonwealth Government, in next considering the need to update the central computing capacity of CSIRONET, should consider the rationalisation of scientific computing in relation to all Government-supported activities, including universities and colleges of advanced education. The resolution of these recommendations will have very significant implications for future policy on computing, particularly scientific and technical computing, within the Commonwealth administration.

34.2.6 It is conceivable that, in the implementation of the above proposals, the CSIRO Division of Computing Research could withdraw from its present R&D activities, other than R&D directly related to CSIRONET. Of the research projects listed in a recent report [7], it appears that perhaps one quarter would be dropped. There do not appear to be any current proposals for a compensating increase in R&D elsewhere.

34.2.7 Usage of resource-sharing networks (computers linked by telecommunications channels), including CSIRONET, is heavily influenced by the policy of Telecom Australia. Apart from a few special cases (e.g. the defence forces), communications links must, by law, be rented from Telecom; present Telecom policy does not, except in some special cases, permit outright purchase. Policy decisions by Telecom on matters such as charges, networking standards, provision of digital transmission capability, and the use of a domestic satellite (currently under examination by the Commonwealth Government) will play a central role in the development of the pattern of computer usage in Australia.

State Government

34.2.8 The various State Public Service Boards co-ordinate their computing activities in a more centralised manner than does the Commonwealth, the pattern usually being that a central bureau offers a service to departments with computing requirements. Some technical computing is performed for the State Governments by statutory bodies and tertiary education institutions which have the capacity to undertake it. As with the Commonwealth, most State statutory bodies are autonomous in their decisions for computer purchase.

Tertiary education

34.2.9 The Universities Council, the advisory body for university funding, considers that computers do not differ, in terms of funding and control, from the other services (such as libraries) provided within universities. It provides within equipment grants to universities unspecified funds for the purchase of computing equipment, leaving to the universities themselves the responsibility for determining priority for computing, in terms of both amount spent and timing of expenditure. At present, and unlike the situation which prevailed prior to 1972, there is no official mechanism for replacing obsolete large computers, since Commonwealth policy is interpreted, by some universities at least, as prohibiting the universities from saving funds over a period of years.

34.2.10 The Advanced Education Council is advised on computer matters by a Computer Committee. This committee considers such matters as the future growth rate of computer power, and the use of networking among college of advanced education (CAE) computers. The committee thus facilitates co-ordination and co-operation between CAE's on the use and sharing of computer facilities.

Private enterprise

34.2.11 The industry as a whole has no formal organisation or policy structure, but the equipment suppliers perform a major integrating function. Most major suppliers have a users association which provides a forum for the exchange of technical information on the use of that supplier's machines.

Technical and trade associations

34.2.12 These bodies provide an integrating force for computer users and service suppliers generally, by providing for meetings of branches, conferences, and exchanges of technical and other information through their publications. Principal among these is the Australian Computer Society Inc, founded in 1966, which has 6,700 members. Its purposes include extension of the knowledge and appreciation of computers, ADP systems and computer controlled systems; furthering the study and application of computer science and technology; development of a code of ethics and definition of a standard of knowledge in computing. Its quarterly publication, the Australian Computer Journal, provides one medium for the dissemination of information on scientific and technical computing in Australia. Other technical associations include the Association for Computer Aided Design and the Australian Institute of Systems Analysts.

34.2.13 Two associations serving the interests of particular sections of the industry are the Computer Users' Association (an association of owners of computing installations) and the Australian Computing Services Association (an association of consultants and service bureaux). Several professional societies have scientific and technical computing interests, and some of these societies have specific groups with a special interest in

computers. These include the Australian Mathematical Society, the Institution of Engineers Australia, and the Operations Research Society of Australia.

34.2.14 Research workers in computer-related fields, in common with research workers generally, tend to place considerable value on international contacts. It is common for such people to be members of a local association such as the Australian Computer Society, and at the same time members of one or more larger, overseas, learned societies.

FUNDING

34.2.15 Most funding for research and development in scientific and technical computing is not identifiable, as it occurs as an inseparable part of the overall budgets of government establishments, universities and private enterprise companies who conduct such R&D in parallel with, or in support of, other work. There are, however, some arrangements for the granting of specific funds for scientific and technical computing projects as part of more general research funding schemes. These are described below.

Australian Research Grants Committee (ARGC)

34.2.16 The operation of the ARGC is described in Chapter 5 of this report. Total ARGC grants, in all areas, were \$7.1million in 1976 and \$9.1million in 1977. There were 51 projects in 1976 and 69 projects in 1977 whose ARGC grants included funds for computing equipment, computer time or computer personnel (e.g. programmers or research assistants). However, there were only two projects specifically in computer science that were supported in 1976, and six in 1977. The amounts granted in the above categories are listed in Table 34.3.

TABLE 34.3

ARGC GRANTS FOR COMPUTING

	Amount Granted (\$'000)	
	1976	1977
Computer Equipment	57.4	130.5
Computer Time	43.5	44.3
Computer Personnel	98.2	105.0
Total amounts granted for		
Computer Science Projects	32	49

34.2.17 These figures suggest that, although many research workers are computer users, there are very few research projects of a high enough standard to attract ARGC support in computer science itself. The ARGC has commented [8] on the sparsity of good applications from computer scientists.

Australian Industrial Research and Development Incentives Board (AIRDIB)

34.2.18 AIRDIB makes grants to industrial companies in support of R&D projects. No breakdown of grants to the computing industry is available, as details of projects are confidential. As a guide, however, in 1975-76 AIRDIB gave grants totalling \$198,000, and \$220,000 in 1976-77, under the industry classification 'office machines'. AIRDIB does not make grants for software R&D, unless it is associated with hardware development.

Radio Research Board (RRB) and Electrical Research Board (ERB)

34.2.19 These Boards are funded by the Commonwealth Government, and by the Electricity Supply Association of Australia (a group of electricity supply authorities) respectively. They make grants for research projects within tertiary education institutions aimed at improving understanding of radio propagation or electricity supply. The philosophy of both bodies differs from that of the ARGC, in that they specify research areas to which priority will be given, and also in that they are willing to support mission-oriented research and development as well as basic research. In 1977, the ERB funded 38 projects to a total of \$219,000 and the RRB funded 65 projects to a total of \$156,000. Although none of the projects was specifically in computer science, 13 of the ERB grants and 11 of the RRB grants were for projects which involved computing. For example, the ERB projects ranged from simulation and mathematical modelling to use of microprocessors for on-line control of power systems.

Indirect funding

34.2.20 As well as the methods described above for direct funding of projects involving scientific and technical computing, there are some sources of aid to the Australian computer industry which indirectly contribute to R&D in the area. One of the most important of these is the structure of tariffs and bounties imposed by the Commonwealth Government in November 1976, following the report of the Industries Assistance Commission on ADP Equipment and Parts [9]. All imports of hardware attract a tariff of 6%, except cathode ray terminals which attract a tariff of 24%.

34.2.21 There is also a bounty for seven years on value added in Australia. The bounty is 20% for the first three years, 15% for the following two years, and 7.5% for the final two years. ASTEC has, however, gained the impression that the existence of this bounty is not widely known in the local computer community.

34.2.22 As a result of the investigations leading to its report, the IAC estimated that the cost of the hardware R&D effort in Australian industry in 1974-75 was \$3.5million. The total turnover of the Australian hardware industry in that year was \$10million. The Australian Computer Society Software Industry Committee, in a study associated with the IAC inquiry [10], estimated that about 7000 programmers in Australia were involved in software R&D, although not all of this would be devoted to scientific or technical ends.

34.2.23 Another mechanism which indirectly contributes to funding of R&D in computing is the Australian Offsets Program. This operates to involve Australian industry, wherever possible, in the development and operation of major equipment systems being purchased overseas for the Commonwealth Government. The program has been used since 1972 to fund 15 software development projects totalling \$9.9million. Four further projects costed at \$1.9million have been approved but not yet commenced.

34.3 DESCRIPTION OF R&D

34.3.1 Because of the diffuse nature of scientific and technical computing and its R&D effort, it has been impossible, in the time available to this study, to collect complete information on all major research programs. Information on establishments conducting R&D, and their programs, has been gathered on a sample basis and the descriptions hereunder should be taken as supplying a broad overview by example only.

34.3.2 In principle there are two categories of computing R&D projects; those aimed at improving the art and science of computing as such, and those projects which are in reality R&D in different areas, but which have a strong component of scientific and technical computing. There is not, however, a clear-cut boundary between the two categories. The survey information which follows is therefore a mixture of the two types of R&D in scientific and technical computing.

COMMONWEALTH GOVERNMENT

34.3.3 Eighteen technical and eight non-technical establishments or organisations were surveyed. The computing activities of 10 of the technical establishments, with a total computing expenditure, in 1976, of less than \$1million each, are summarised in Table 34.4.

TABLE 34.4

COMMONWEALTH GOVERNMENT-SMALLER TECHNICAL ESTABLISHMENTS CONDUCTING R&D

<u>Establishment</u>	<u>Applications</u>	<u>Nature of Facility</u>
Anglo-Australian Observatory	Light intensity (photon counting); data acquisition; automatic control of micro-densitometer; telescope control; reduction of spectral data and 2-dimensional, star pictures; galaxy modelling.	7 minicomputers

Antarctic Division, Dept of Science	Computations arising from research in upper atmosphere physics, cosmic rays, glaciology, biology.	External computing facilities
Bureau of Mineral Resources	Geophysical processing; geological data bases; geochemical data acquisition and processing; magneto- telluric data acqui- sition and processing systems; marine geo- physical data acquisition and processing systems; seismic data presenta- tion systems.	9 minicomputers, external facilities
Central Studies Establishment (Department of Defence)	Simulation; operations research calculations.	Medium sized computer
Department of Construction	Calculation of duct sizing; roads and structures; various other programs for engineering and architectural design.	External computing time (15 minicomputers on order)
Engineering Development Establishment (Department of Defence)	Data acquisition and analysis.	Minicomputer
Division of National Mapping	Telescope control and data collection; earth rotation and polar motion; universal time; thematic map production; digitising topographic and other cartographic information.	4 minicomputers and external computing facility
Department of National Development (Petroleum Branch)	Energy forecasting models; project analysis.	External computing
Department of National Development (Energy Branch)	Economic analysis and econometric modelling.	External computing
Snowy Mountains Engineering Corp.	Various engineering calculations.	Medium sized computer, small use of external facilities

34.3.4 The Australian Atomic Energy Commission's Applied Mathematics and Computing Division uses a medium-to-large computer with replacement value about \$1.5million. This computer is connected to 36 terminals, many of which are minicomputers capable of stand-alone operation. Recurrent expenditure in 1976 was \$700,000, of which about 60% was rental of the main computer. Systems software is rented for \$1,000 per annum. No use was made of consultants in 1976. Technical computing and computing R&D include various projects in applied mathematics, the development of a distributed computer network, operating systems development and graphics projects.

34.3.5 The Australian Bureau of Statistics, with an expenditure on computing in 1976 of over \$11million, and installed equipment with an initial cost of about \$13.5million, is concerned entirely with computations arising in connection with official statistics. Its R&D is directed to providing a better integrated information system and a suitable, high-level, user-oriented language to facilitate its use. Some use is made of foreign consultants. Software packages purchased in 1976, nearly all systems software, cost about \$12,000, two thirds of which was for packages of Australian origin. Some use was made of specialised, external, computing services for magnetic tape and microfilm conversion.

34.3.6 The Bureau of Meteorology had an installed capacity in 1976 with a replacement cost of \$5.1million, and an expenditure on computing in that year of \$1.4million. The equipment is used for satellite tracking, extraction and processing of data, meteorological modelling, water studies and climatological services, operational forecasting and hydrometeorological services. Developments include enhancement of a message switching system, a variety of modelling activity (flood forecasting, lake evaporation and orographic rainfall), wave research, aerial rainfall distribution, eigenvalue analysis, a weather modelling project (jointly with CSIRO) and an investigation of the low-level, atmospheric boundary layer. No software was purchased, nor was any use made of consultants in 1976.

34.3.7 The CSIRO Division of Computing Research has as its primary computing tool CSIRONET, which comprises a large computer and an Australia-wide network with 60 nodes and 600 terminals (the number of terminals is increasing at about 15% per annum), and which has a replacement cost of about \$6.5million. Recurrent costs for the financial year 1976-77 were about \$4.7million, notable components of which were salaries (38%) and Telecom lines (9%). In 1977-78 the Division of Computing Research used 20% of the Division's computing resources. The 65 scientists and other professional staff spent 28% of their time in constructing new systems software, 29% in constructing applications software and 24% on scientific research other than constructing software. Current R&D projects relate to operating systems, communication systems, computer language development, data base systems, simulation and systems analysis, picture processing and graphics. A detailed listing is available in the Division's annual report [7].

34.3.8 The Government Aircraft Factory uses computers for a variety of engineering applications. Several engineering computations associated with missile development, wind tunnel analysis, aerodynamic performance, aircraft flutter and structural analysis, are carried out at the Aeronautical Research Laboratories (Chapter 25 gives further details). Seven minicomputers are used for display purposes in connection with flight and missile simulation and other graphics display purposes, environmental data analysis and fatigue data processes, numerical control of machine tools and digital testing of production electronic circuits. Total computing expenditure in 1976 was \$1.2million. Expenditure on software packages was negligible and there was no expenditure on consultants.

34.3.9 In 1976 Telecom Australia devoted about 15% of its computing power, which has a replacement value about \$7million, and about half the external computing expenditure of \$1.7million, to technical and scientific computing. Ten percent of the computing centre's professional staff was involved. Development work included stored processor controlled (SPC) exchanges, minicomputer-based meter reading and monitoring, a video text system, an advanced communication experiment, host resident microprocessor support software, microwave holography, word processing extensions and investigations of rainfall attenuation. Foreign systems-software packages (\$10,000) and applications-software packages (\$10,000) were purchased in 1976, and in that year no use was made of private consultants. Of the 26 Telecom Research Laboratory reports listed in March 1977 for general distribution, eight related to digital engineering projects, five to digital transmission and one to computer simulation of a physical process (the Gunn effect). Telecom also has 30 or more computers and microprocessors in use for message switching in connection with the Common User Data Network (CUDN) and experimental SPC exchanges.

34.3.10 The Defence Research Centre, Salisbury (Department of Defence) Computing Services Group has a computer with a replacement value of \$7million, and spent \$3million on computing in 1976. The computing resources are spent almost entirely on technical computing associated with the function of the Establishment. New developments include real time software, a data archiving system and an engineering materials data base. Systems software packages to the value of \$60,000 were purchased in 1976, one quarter being of Australian origin. No use was made of consultants. In addition to the computing activities of the Computing Services Group of the Defence Research Centre, Salisbury about 30 minicomputers are used by various other specialist groups for experimental purposes. The computing activities of the Department of Defence, Aeronautical Research Laboratories are described in Chapter 25.

34.3.11 The activities of the eight, non-technical, Commonwealth Government users which were surveyed are summarised in Table 34.5.

34.3.12 With each of the two respondents with large installations, a sum of between \$1million and \$3million was devoted to developing systems programs in 1976, and a much smaller amount to technical calculations. The other users each spent between \$100,000 and \$300,000 on technical computing in 1976. In 1976, two of the users made use of consultants

(Australian), one to modify and install an imported software package, and one for advice. About \$21,000 in all was involved, including the cost of the imported package just mentioned. Apart from this package and one minor statistical suite, no software was purchased. In the case of four of these units, wide usage of technical programs by a number of professional groups (economists, econometricians, communications specialists, industrial engineers, surveyors, and cartographers) was reported.

TABLE 34.5

AUSTRALIAN GOVERNMENT - NON-TECHNICAL USERS OF
SCIENTIFIC/TECHNICAL COMPUTING

<u>Instrumentality</u>	<u>Technical computing activity</u>	<u>Computing facility</u>
Attorney-General's Department.	Legal data information retrieval system	Bureau facilities
Australian Wool Corporation	Minor statistical calculations	External facility
Department of Administrative Services	Automated cartography and surveying	Three minicomputers
Department of Business and Consumer Affairs	Systems programs to improve efficiency of network	Customs network
Industries Assistance Commission	Economic modelling	External
QANTAS	Operations research calculations; new systems programs	Substantial computing facility
Reserve Bank	Statistical and simulation	External
Bureau of Agricultural Economics	Survey processing; economic modelling	External

STATE GOVERNMENTS

34.3.13 Five State Government technical establishments surveyed were concerned with energy supply (four electricity generating boards and a gas and fuel corporation), four with road construction and road research activities, and one with water supply. Their technical activities are predominantly engineering in character, and are summarised in Table 34.6.

TABLE 34.6

STATE GOVERNMENT - TECHNICAL USERS

<u>Primary activity</u>	<u>Technical use and development</u>
Energy supply (5 users surveyed)	Load flow studies; generation planning; simulation of power systems; environmental studies; line parameters and sag curves; project and maintenance job control; fault reporting; metering processing; structural engineering calculations; planning of open cut mining; modelling of boiler steam cycles; pipeline network analysis; economic modelling.
Road construction (4 users)	Land survey; automatic, engineering and survey drafting; simulation of traffic and other modelling in traffic engineering; road location, design and construction (including earthworks); bridge design; development of computer controlled road making equipment; measurement of driver behaviour; management of information-retrieval systems.
Water supply (1 user)	Construction and maintenance job control; storage and sandbed water source modelling; water reticulation analysis.

34.3.14 Only two of the users in Table 34.6 used consultants in 1976, to the extent of about \$30,000 for software construction and \$5,000 for advice: the consultants were all Australian. Seven had purchased software packages in 1976, systems-software in six cases (for a total cost of \$98,000), and applications-software in three cases (totalling over \$30,000 in value). With three exceptions, technical computations were carried out with machines which were used predominantly for accounting and administrative calculations. Two of the machines dedicated to technical computations have a replacement cost of about \$200,000 each, one (owned by a main roads board) of over \$1million. Typically, 20 to 30 per cent of shared facilities are devoted to technical computations.

34.3.15 The general picture which emerges is of usage of computing facilities predominantly by engineers, with some use by other specialists (surveyors, geologists, biologists, draftsmen, statisticians), and new development effort concentrated primarily on applications software.

34.3.16 State government non-technical users are summarised in Table 34.7.

TABLE 34.7

STATE GOVERNMENT - NON-TECHNICAL USERS

<u>Primary activity of organisation</u>	<u>Technical uses and developments</u>
Health (3 users surveyed)	Real-time data acquisition and analysis in a biomechanical environment; rate of transfer analysis in nuclear medicine; radiotherapy calculations; dynamic behaviour of spinal cord; stress-strain of bio-materials; interfacing with autoanalysis unit; laboratory data management.
Maritime services (1 user)	Port simulation.
Police (2 users)	Enhancement of software for message switching and line enquiry system.
Primary industry (1 user)	Statistical analysis of biological data of 500 research projects by 17 biometricians. Mainly use of CSIRONET.
PSB computer bureaux (3 users)	Various engineering and survey calculations; design and analysis of experiments; star position calculations; mine subsidence; rainfall analysis; time series analysis; epidemiology studies; various agricultural calculations including linear programming and scheduling calculations; migratory studies of wild ducks; geodetic and photogrammetric surveying calculations; adjustment of higher school certificate marks; simulation of forest growth; water resources and storage studies.
Transport (1 user)	Civil engineering design; track clearances and simulation.

34.3.17 Only 2 of the 11 users in Table 34.7 employed consultants in 1976, 1 for software and 1 for advice. The total expenditure in 1976 was about \$15,000, and the consultants employed were Australian. Seven used purchased software packages in 1976 (\$111,000 for systems software, and an unstated, but almost certainly much smaller amount for applications software in 1976), mainly imported.

TERTIARY EDUCATION INSTITUTIONS

34.3.18 Twenty-five university or college of advanced education (CAE), departments of computer science or their equivalents were surveyed. Table

34.8 shows the distribution of department sizes, measured by the number of full-time equivalent academic staff.

TABLE 34.8

DEPARTMENT SIZES : FULL-TIME-EQUIVALENT ACADEMIC STAFF

<u>No. of full-time Staff</u>	<u>No. of Institutions within full-time academic staff range</u>		
	<u>CAE's</u>	<u>Universities</u>	<u>Total</u>
0- 5	4	4	8
6-10	5	6	11
11-15	0	2	2
16-20	0	1	1
21-25	1	0	1
over 25	2	0	2

34.3.19 This shows that most tertiary-education departments of computer science are small, 19 out of the 25 having 10 or fewer full-time academic staff. Department size, the teaching workload, and time spent in supporting computing outside the department, all have an effect on the amounts of time full-time academic staff can spend on research; the net effect is that the research output of these departments is low. Overall it can be concluded that there are many small departments with resources spread thinly, giving little opportunity for academic staff to conduct intensive research.

34.3.20 It is also known, although precise data are not available, that some computer science research is carried out in academic departments other than departments of computer science. Some tertiary institutions teach and carry out research in computer science but lack a formally constituted computer science department. Moreover, relevant research is carried out by people who are not members of a computer science department and who, in some cases, do not consider themselves to be computer scientists. For example, some research workers in the area of 'Numerical Methods' are members of mathematics departments, and some are members of computer science departments, while hardware-related research, including research in the microprocessor area, is most commonly carried out in electrical engineering departments. The little survey material available does not allow the drawing of a conclusion that there are, or are not, gaps in the areas of computer science presently covered by academic research workers.

34.3.21 Higher degree students provide the other principal source of manpower for research in tertiary institutions. Because such students are enrolled in a variety of academic departments, and because it is not always clear whether their research should be labelled 'Computer Science', any attempt at estimating the number of research students whose work is in computer science is likely to be grossly misleading. However, there is a general feeling within the profession that the number of computer science

research students is low in comparison with the numbers in adjacent disciplines.

34.3.22 As well as computer science departments, other departments in tertiary institutions were surveyed to ascertain the extent of possession and usage of computers. It was found that computers are being used in a very wide range of disciplines, a number of which are not traditional computer users.

34.3.23 Departments with computers include the following: physics, chemistry, all branches of engineering, architecture, biological sciences, agriculture, geology, economics, accounting, education, music, english (phonetics), psychology and medicine. The majority of these machines, and particularly the newer ones, are minicomputers which range from very small machines (with replacement costs from \$4,000), through medium sized minicomputers (typically a \$50,000 configuration) to quite powerful systems (\$100,000 and above); most of the machines are small to medium sized. The dramatic drop that has been occurring in the prices of medium sized installations based on minicomputers suggests that their numbers will continue to grow. Non-administrative users of computers in the tertiary institutions surveyed apply them to three main areas: research calculations, teaching, and control of experiments.

INDUSTRY

34.3.24 The use of computing within the private sector is very widespread and is growing rapidly. Table 34.9 gives, among other things, an indication of the extent of usage of computers by various industry groups in the private sector and the growth rate over 1975-76 [3]. This very wide usage, and the fact that scientific and technical work is usually undertaken together with non-technical and even routine accounting calculations, makes it especially difficult to survey private sector conduct of R&D in scientific and technical computing. It must therefore be stressed again that what follows represents a brief summary of information derived from a survey of a very small proportion of the private sector. Chapter 27 includes additional, but not comprehensive, information on hardware R&D among Australian companies.

Hardware suppliers

34.3.25 Two suppliers of machines used largely for technical computations were surveyed. One, a supplier of large machines (almost half its machines sold in Australia having an installed value of over \$1million) reported that just over half its machines were used for technical calculations comprising communications (11% of installed machines), education (11%), routine technical and scientific applications (13%), process control (4%) and medical applications (8%), as well as technical or scientific work conducted at the company's own data centres. The other supplier produces smaller machines (84% of its installed machines have a value of less than \$100,000), and reported that all usage was technical, comprising

25% education, 10% technical and scientific calculations, 20% communications, 10% monitoring of experiments, 10% process control, 10% research computations, and 15% other unspecified technical purposes.

TABLE 34.9
DISTRIBUTION OF NUMBERS OF COMPUTERS
BY INDUSTRY 1975-76

	<u>1975</u> <u>Total</u>	<u>1976</u> <u>Total</u>
<u>Government</u>		
Cwlth	136	223
Defence	44	45
States	82	106
Local	28	62
Instrumentalities	53	62
Utilities - Power	37	40
Utilities - Other	19	22
<u>Total</u>	<u>399</u>	<u>560</u>
<u>Education and Research</u>		
Universities	127	155
CAE's, Technical Colleges	46	50
Schools	3	2
Computer Schools	2	2
Research	104	110
Medical	19	33
Other	1	1
Training provided by manufacturers	15	15
<u>Total</u>	<u>317</u>	<u>368</u>
<u>Financial</u>		
Assurance	34	38
Banks	76	93
Finance	27	40
Holding Companies	4	11
Insurance	59	70
Professional	7	24
Stock Exchange	12	13
<u>Total</u>	<u>219</u>	<u>289</u>
<u>Farming, Agriculture</u>		
Agricultural Agents	5	5
Production	5	9
Marketing Boards	16	12
Newsprint	14	16
Woolbrokers	19	17
<u>Total</u>	<u>59</u>	<u>59</u>

<u>Building Construction</u>		
Construction	4	10
Building Materials	19	46
Paint	6	6
<u>Total</u>	<u>29</u>	<u>62</u>
<u>Chemicals</u>		
Chemicals	13	16
Drugs	26	30
Soap	15	12
Importers	5	7
<u>Total</u>	<u>59</u>	<u>65</u>
<u>Mining, Metals, Cars</u>		
Mining	23	35
Iron and Steel	47	61
Aluminium	13	14
Other metals	14	17
Motor manufacturing	4	3
Motor spares	32	47
Oil and Petrol	26	30
<u>Total</u>	<u>159</u>	<u>207</u>
<u>Manufacturing, Distribution</u>		
Electrical, Electronics	53	68
Engineering	80	100
General	81	118
Office Equipment	2	3
Packaging	12	19
Plastics	13	18
Rubber	14	12
Textiles	24	29
<u>Total</u>	<u>279</u>	<u>367</u>
<u>Household Suppliers</u>		
Food	46	69
Biscuits	7	10
Drink and Tobacco	19	29
Clothing	12	13
Furniture	1	4
Wholesalers	26	42
Retailers	24	41
<u>Total</u>	<u>135</u>	<u>208</u>
<u>Services</u>		
Publishing	50	55
Transport	22	23
Airlines	33	34

Shipping	11	14
Advertising	6	8
Direct Mail	5	4
Miscellaneous	17	39
Service Bureau	133	161
Mfg Service Bureau	39	44
<u>Total</u>	<u>316</u>	<u>382</u>
<u>Grand Total</u>	<u>1971</u>	<u>2567</u> [11]

34.3.26 The companies together had an income of over \$1million in 1976 for systems software (20% local content) and technical applications software contracts of over \$3million.

Consultants and technical/scientific software suppliers

34.3.27 Ten such suppliers were surveyed, two of them operating from tertiary education institutions, and one oil company offering a systems-software package developed by its overseas parent company. Typically, such companies earn their income by supplying systems software or technical applications software to private-sector companies, and to a lesser extent to the Australian Government. A significant amount of software is also exported. Typical applications software supplied covers telemetering, data acquisition, civil engineering graph analysis, critical path analysis, road design, hydrology, fatigue analysis of aircraft, and mineral exploration analysis. Development of such packages is carried out either on the customer's computing equipment, or on bureau or in-house machines.

Service bureaux

34.3.28 Three bureaux using large machines (average replacement value \$4.8million) and one using a small machine (replacement value \$35,000) were surveyed. The small bureau reported that 60% of its computing resources were used for customers' technical calculations, and 90% of the effort of the professional staff was spent in constructing applications software (structural analysis and design, operations research, modelling, various civil engineering applications).

34.3.29 The three larger bureaux reported that, on the average, about two-thirds of their income came from private users, and one-sixth each from Commonwealth and State governments; an unspecified, but apparently high proportion of the income was, however, derived in the non-technical area. For these bureaux, systems programming under contract averaged ten man-years in 1976, and technical and scientific programming three. Income from technical and scientific software or hardware contracts averaged \$50,000, almost one half of which was from foreign clients. The main technical and scientific R&D projects carried out were concerned with network protocols, telephone traffic and data base construction. There was one small hardware project on the construction of communication interfaces. Overall, the bureaux appeared to be active and commercially viable operations, making a substantial contribution to the computing power and expertise available in the private sector.

Private sector users with own installation

34.3.30 Eleven such users were surveyed, subdivided by industry into food and drink processing(two users), chemical and petrochemical(three), mining(two), iron and steel making(three), and aerial mapping(one).

34.3.31 One of the food and drink processing companies (a brewery) was concerned primarily with systems software (file comparison, computer log analysis and test generation). This company had built its software in-house, with the help of Australian contract programmers. In 1976 about 1.5% of total expenditure on computing, excluding salaries, was spent with a bureau for running unspecified technical calculations for three food technologists, two industrial chemists and one operations research officer, the in-house equipment (with a replacement cost of \$900,000) being used primarily for commercial work. The other user, a sugar mill, employed two small computers, each with a replacement value of \$120,000, for control purposes (bagasse loft automation, dump steam condenser control and pan stage control).

34.3.32 The three chemical manufacturers used about half the installed machine capacity (which averaged \$1.5million each), and some bureau time for technical calculations. Altogether, in 1976, the three manufacturers spent \$45,000 on systems-software packages (compiler, teleprinter (TP) monitor) 25% of it of Australian origin. Applications under development included financial models, linear programming, statistical analysis, plant simulation and network analysis. Two companies used 15% of their computer resources in developing new systems and technical applications programs, and 25% in running them. The third company used 50% of its computing resources for developing programs. Two of the companies had fifteen professional staff, on average, associated full-time with computing, the third listed one member of professional staff only. The numbers of casual users of computers for technical and scientific calculations varied between 6 and 70.

34.3.33 Of the three mining companies, two are similar in their scale of operation. In 1976, each spent about 10% of its computing budget in technical computing (mine planning, geological and operations research calculations, simulation of shaft ventilation, stress analysis and general statistical analysis) for which three of their four or five computers respectively were used. In 1976, applications software worth \$11,000 had been purchased by one company, 10% of it (all mining software) from overseas, and systems software totalling \$38,000 (data base management and on-line supervisor) by another.

34.3.34 Australian consultants were used to some extent (\$10,000p.a.) by one company in 1976. Twelve professional staff of one company (engineers, geologists, surveyors and managers) used computing equipment for their technical calculations. One company was developing a number of programs (ore reserve estimates, mine planning schedules, railroad simulation, financial modelling). A second mining company, which has developed a \$4million, statewide network, and in 1976 used \$40,000 in bureau time (a quarter of it abroad), spent \$43,000 in 1976 for

applications software (40% of it graphics software, the rest unspecified, 20% of it being Australian developed). Of this company's annual computing budget of \$750,000, 6% was spent in developing new systems software, 40% was spent in developing programs for scientific and technical applications (analysis of exploration data, linear programming, graphics and plotting applications, mineral inventory and ore body modelling, mine-design simulation studies, engineering design) and 50% in running scientific and technical calculations. Some 17 professional staff were associated with the computing facilities (constructing new systems and technical programs) and these facilities were used by 70 staff members in their technical work.

34.3.35 Of the three installations primarily concerned with steel-making calculations, one used equipment with a replacement value of \$250,000, the other two used equipment each with a replacement value of about \$3million. Two of the five machines at the small installation were used in 1976 for developing process-control programs, analytical spectrometer support software and metallurgical process modelling, half of the effort of four programmers being used for this development. The running of technical programs, which utilised about 40% of computer resources, covered applications in statistical analysis, modelling of metallurgical processes and analytical spectroscopy.

34.3.36 The two major installations employed in the one case ten machines, in the other six, for technical calculations, three or four other machines being used for other purposes. Applications cited for individual computers include process control, spectroscopic analysis, numerical control of machine tools and various technical calculations (concerned with the thermochemistry of metallurgical processes, scheduling of operations, mine planning and management of raw materials). One spectrographic-analysis package had been purchased in 1976.

34.3.37 A breakdown of running expenditure in 1976 was provided for only one installation. An expenditure of \$800,000 (excluding salaries) included 8% for developing new systems software, 3% for developing applications software, and 3% for running technical applications programs.

34.3.38 The professional staffs in the two larger installations numbered 17 and 95, and the proportion of effort spent on constructing new systems programs (5% and 10%) and new technical software (10% and 12%) was quite low. The installations were each used by about twenty professional staff for their technical calculations (engineers, metallurgists, chemists, physicists). Technical programs under development include programs for mine planning, recording pellet production, quality control of raw material, optimisation of bulk yield, heat-transfer analysis, scheduling of operations and spectrographic analysis.

34.3.30 The general picture which emerges from this survey is that the companies concerned - probably typical of the larger companies in the private sector - make little or no use of consultants, and are self-contained as far as their computing facilities are concerned.

34.3.40 The other company surveyed was an aerial mapping company. With one computer, with a replacement value of \$80,000, the 1976 computing budget was \$50,000 (excluding salaries). Almost 30% of this budget was spent in developing photogrammetric-survey programs, digital terrain models and graphics programs, and 50% in running photogrammetric calculations, block adjustments, contour plotting and in processing digital terrain models. Programs for digital terrain models and servicing a flatbed plotter, representing an outlay of \$15,000, were under development. All software used was produced by the company itself.

34.3.41 The aerial survey industry is an interesting example of a service industry which is becoming increasingly dependent on computers: about 5% of the turnover of the industry is computing, and about a quarter of the \$250,000 needed to set up the initial plant for an aerial survey unit is the cost of a computer. Many small companies farm-out parts of the process to each other and to computer service bureaux. The industry employs perhaps 300 throughout Australia, of whom 15 are employed on computing.

NOTES AND REFERENCES

1. B.S. Thornton, and P. Stanley, 'Report on Factors Affecting the Economics and Use of EDP Resources in Australia.' Foundation for Australian Resources, Sydney, 1975
2. L.T.M. Whittet, 'A Recent Survey Concerning Data Processing in Australia.' Bulletin of the N.S.W. Branch of the Australian Computer Society, Sydney, 1977
3. Data Trend EDP Manual 1976. Rydge Publications, Sydney, 1976
4. B.W. Smith, and B.Z. Ferranti, 'The Present and Future Use of Computers in Australia and Employment Implications.' Australian Computer Society, Canberra Branch, ACT 1976
5. US Bureau of Commerce Market Research Summary - Computers and Peripheral Equipment, Australia and New Zealand. US Department of Commerce, 1976
6. B.O. Szuprowicz, 'Study Uncovers World D.P. appetites.' Computerworld, 1977
7. CSIRO Division of Computing Research Annual Report 1977-78, CSIRO Canberra, 1978
8. Australian Research Grants Committee Report 1973-75, ARGC, Canberra, 1975.
9. Industries Assistance Commission Report: 'ADP Equipment and Parts.' Australian Government Publishing Service, Canberra 1976
10. Australian Computer Society, Sydney, 1975
11. Note that there is a slight difference between the 1976 grand total shown here and the corresponding figure given in Table 34.2. The cause of the discrepancy is unknown, although it possibly arises because of the difficulty, in some instances, of defining the word 'computer'.

CHAPTER 35

TRANSPORT

Photograph: The Interscan 'flare' antenna installed for evaluation at Melbourne Airport. The flare system provides height guidance to aircraft just prior to touchdown.

(Photograph courtesy Commonwealth Department of Transport).

CHAPTER 35

TRANSPORT

35.1 INTRODUCTION

DEFINITION OF AREA COVERED

35.1.1 This Chapter covers the technical and economic aspects of research and development related to the transportation of people and goods. It covers transport planning, transport operations and transport equipment. It encompasses road, rail, air and sea transport. It further includes the handling of freight and materials where this is identified as a transport activity.

35.1.2 The approach adopted has been to provide a descriptive review of research and development activity. Key organisations in the government, tertiary education and private sectors were contacted and information was obtained by personal interview as far as practicable. The survey was supported by available background literature. This method was considered to be essential for a meaningful descriptive coverage of the transport sector to be obtained. Wherever possible, quantitative supporting information was collected; however, the nature of the review and the limited time schedule did not allow a rigorous approach to be taken here. It is emphasised that such information, where it appears, is provided only as a guide for general comparisons to be made between sectors and between fields of activity.

35.1.3 Transport is not an end in itself but is an intermediate service, since the demand for it is derived from the demand for other activities. So by its very nature the transport field has close links with other areas, several of which fall into other categories of review for ASTEC. In order to define the scope of this paper as clearly as possible a set of boundaries is described in the notes [1]. In general, it will be noted in the text where a topic being discussed may overlap with another review area.

35.1.4 The criteria adopted by the Department of Science for Project SCORE were used as guidelines for this review. They require that R&D should be identified by two major factors:

- . a degree of novelty and originality
- . sufficient scope to be applicable (or have the potential of being applicable) to more than one situation or to society as a whole.

35.1.5 In the transport sector much activity which has traditionally been regarded as research does not fall within the above guidelines and so some judgement was needed to determine where demarcation lines should be drawn. Amongst transport operating authorities and equipment manufacturers much of this work is ongoing development which may fall outside the first criterion. In private industry in particular, R&D is heavily weighted towards experimental development with applied research being undertaken mainly by a few large organisations. Among government bodies, research is often directed to a specific geographical area and so the second criterion is not met. In particular, this will exclude much work of a research nature towards problems in transport planning and policy formulation.

35.1.6 The approach taken in this paper is to describe the broad framework of the transport sector in Australia and to discuss within the context of this framework the activities and funding which fall within the guidelines. In general terms these will be drawn from the following:

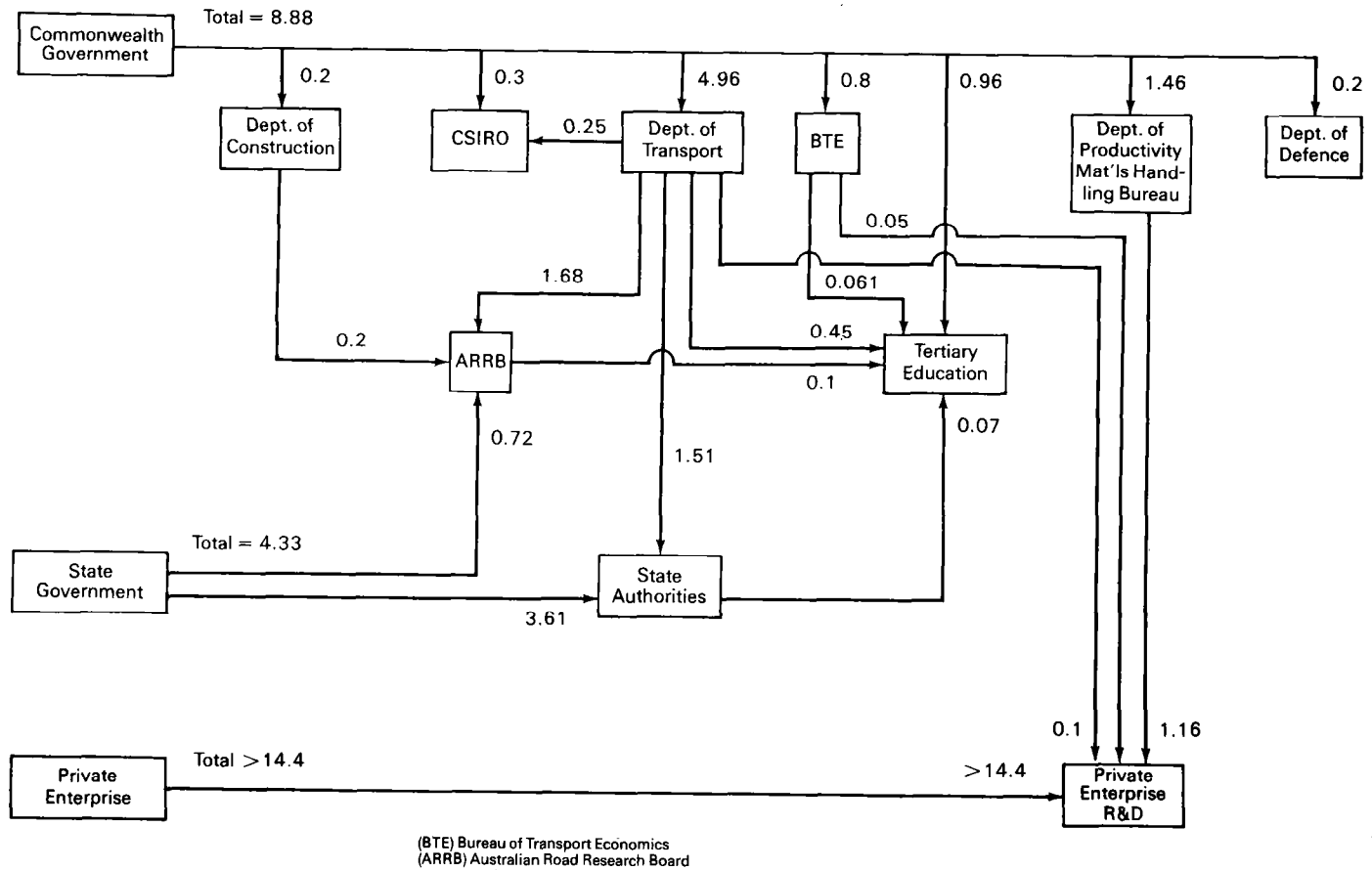
- . improvement of knowledge about the nature of existing transport systems.
- . development of new methodologies for evaluating transport investments.
- . research into new ways of regulating transport.
- . development of new techniques and equipment for performing specific transport tasks.
- . development of new transport technologies.

35.2 ORGANISATION AND FUNDING

35.2.1 R&D activity in transport is distributed across a large number of organisations within Commonwealth and State government, the tertiary education sector, and private enterprise. These include bodies involved with the planning and improvement of transport, with transport operations and with equipment manufacture. In general very few bodies are recognised solely as transport research organisations.

35.2.2 The major funding links between the various spheres of activity are shown in Figure 35.1. These funding levels are approximate but can be used to draw comparisons between areas. A breakdown of these funds by source is given in Table 35.1 and it can be seen that a total of some

FIGURE 35.1
MAJOR FLOWS OF FUNDS IN TRANSPORT R&D
1976-1977 (\$MILLION)



\$28million was devoted to transport R&D in 1976-77. Table 35.2 summarises the distribution of these funds amongst the sectors of performance.

TABLE 35.1

SOURCES OF R&D FUNDS IN 1976-77

	\$million	(%)
Commonwealth	8.88	32
State	4.33	16
Private	<u>14.4</u>	<u>52</u>
Total	<u>27.61</u>	<u>100</u>

Source: Bureau of Transport Economics.

TABLE 35.2

RECIPIENTS OF R&D FUNDS IN 1976-77

	\$million	(%)
Department of Transport	0.97	3.5
BTE	0.69	2.5
CSIRO	0.55	2.0
Materials Handling Bureau	0.30	1.2
Department of Defence	0.20	0.7
ARRB	2.50	9.0
State Authorities	5.05	18.3
Tertiary Education	1.64	5.9
Private	<u>15.71</u>	<u>56.9</u>
Total	<u>27.61</u>	<u>100.0</u>

Source: Bureau of Transport Economics.

35.2.3 At the Federal level, the Commonwealth Department of Transport is involved with all modes of transport. Its tasks include the provision of transport services, enforcement of standards, together with the development and implementation of transport policy. The structure of the Department and its place within the Transport Portfolio are shown in Figure 35.2. The Department's main role related to R&D is the co-ordination of planning and research which, historically, has concentrated upon roads and urban transport. There is some R&D activity within the Road Safety Branch of the Land Transport Policy Division, which maintains close links with State road safety bodies, universities and overseas organisations. The Department administers the Transport (Planning and Research) Act 1974 on a co-operative basis with the States. The Act is designed to encourage a co-ordinated approach to transport research by each State. The Act is described in the next section and the combined funds allocated under it in 1976-77 are indicated in Table 35.3.

The Department also manages Australia's involvement in the Road Research Program of the Organisation for Economic Co-operation and Development (OECD). Australia is represented at steering committee meetings by a Department officer, or by the Executive Director of the Australian Road Research Board (ARRB) as an alternate member. The responsibility of maintaining an information link with the OECD International Road Research Documentation System has been delegated to ARRB.

TABLE 35.3

SUMMARY OF TRANSPORT (PLANNING AND RESEARCH)

ACT FUNDING IN 1976-77

<u>State</u>	<u>Combined funds (Commonwealth and State con- tributions) (\$million)</u>	<u>Amount attributed to projects falling within the R&D criteria (\$million)</u>
NSW	4.64	1.90
Vic	3.20	0.91
Qld	1.84	0.59
SA	0.88	0.34
WA	1.12	0.42
Tas	0.32	0.12
Total	<u>12.00</u>	<u>4.28</u>

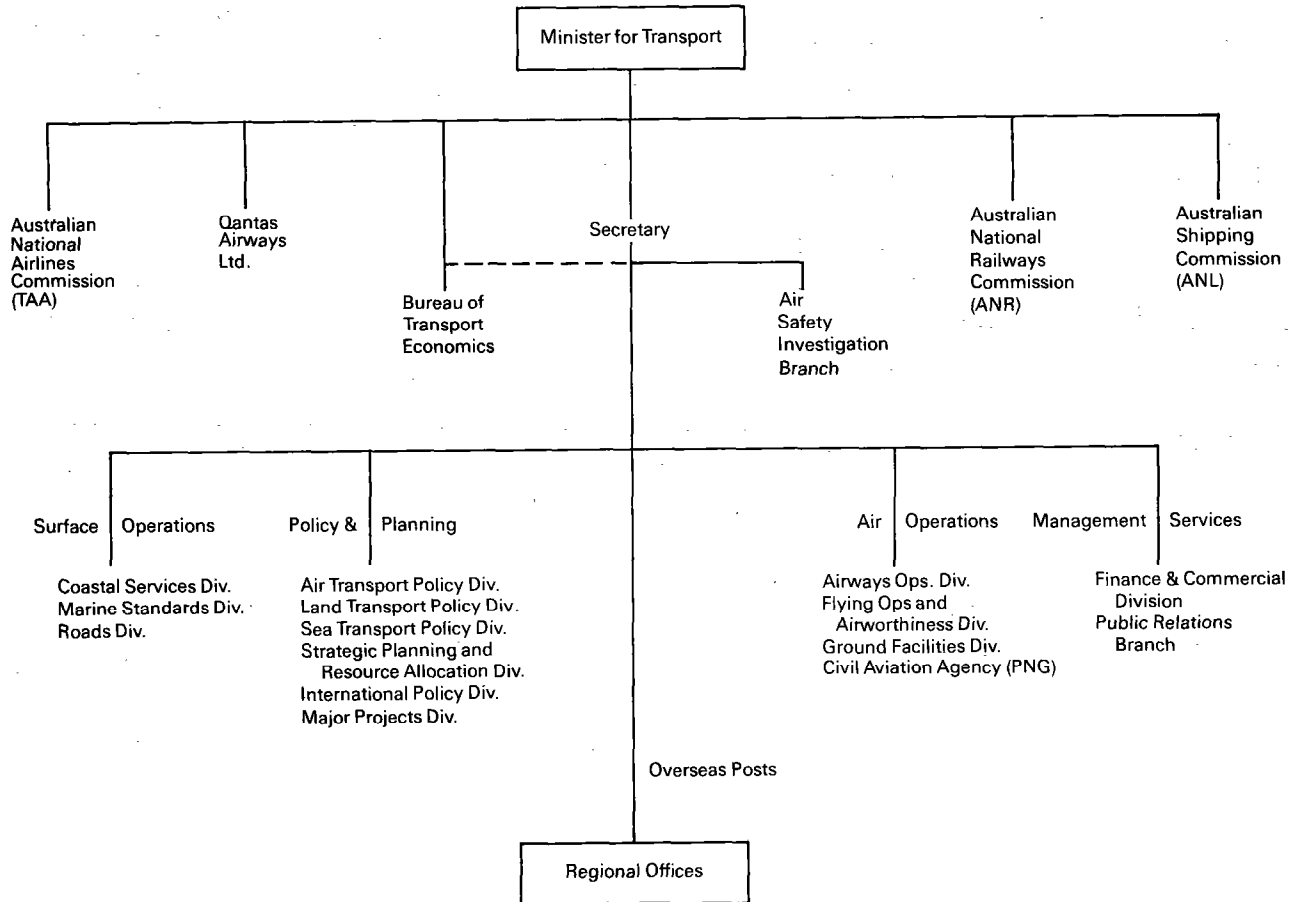
Source: Commonwealth Department of Transport.

35.2.4 The Department is involved with air transport as part of its obligations under the Air Navigation Act. This gives the Department total responsibility for control of all forms of air transport in Australia. To fulfill these obligations, the Department provides a complete infrastructure of airports, navigation, communication and support facilities, and is responsible for their operation and maintenance.

35.2.5 R&D effort is required progressively to improve the performance, efficiency and cost effectiveness of these systems. Further planning and development is required to accommodate future needs. Recently the main effort in this area has been towards Interscan, a microwave landing system being developed for civil aviation. This project is being undertaken by the Departments of Productivity and Transport, the CSIRO Division of Radiophysics, Sydney University, and Amalgamated Wireless (Australasia) Ltd. The Department of Transport provided some \$0.78million in funding for Interscan in 1976-77. In addition, CSIRO contributed \$0.23million from its own budget.

35.2.6 The Bureau of Transport Economics (BTE) is an independent professional research body located for administrative purposes within the Department of Transport. It has recently been expanded due to the amalgamation of the old BTE with the Commonwealth Bureau of Roads. The

FIGURE 35.2
COMMONWEALTH TRANSPORT PORTFOLIO



new body continues the tasks of the previous two, undertaking research and evaluation work associated with Commonwealth programs for all transport modes. This includes development of evaluation techniques, pricing strategies and assessment of transport systems.

35.2.7 The Australian Transport Research Forum (ATRF) was established in 1975 as a medium for information exchange on topics of transport research. It was formed through the initiatives of the BTE and the various State departments of transport. Its forums are largely self-supporting but receive grants from the Commonwealth and the States. Also a Transport Outlook Conference is organised and funded entirely by the BTE to stimulate awareness of future developments. The major papers are prepared mainly by the BTE, but participants are drawn from a wide range of transport bodies.

35.2.8 Within the Department of Productivity, the Materials Handling Bureau (MHB) is active in the development and testing of containers and packages, and it maintains close links with the materials-handling industry. It is also concerned with national standards and regulations, and with the dissemination of information. The Department administers the Industrial Research and Development Incentives Act 1976, under which grants are made for R&D in private industry. A summary of grants related to transport, awarded in 1975-76 and 1976-77 is presented in Table 35.4. Approximately \$1.16million was devoted to transport related areas in 1976-77, out of a total of \$14.4million over all fields.

TABLE 35.4

INDUSTRIAL R&D INCENTIVES GRANTS RELATED TO TRANSPORT

		Grants made (\$million)	
		1975-76	1976-77
Transport -	road	1.08	0.73
	rail	0.12	0.17
	air	0.075	0.04
	other	0.04	0.05
Transport and Storage Containers		0.10	0.12
Engines		<u>0.16</u>	<u>0.05</u>
Total		<u>1.575</u>	<u>1.16</u>

Source: Industrial R&D Incentives Board, Annual Reports for 1975-76, 1976-77.

35.2.9 The Engineering Development Establishment (EDE) within the Department of Defence is undertaking work which has a likely application to the road transport industry. Current programs include the development of ancillary equipment for heavy vehicles and investigation of alternative engine fuels.

35.2.10 Within CSIRO, the participation in the Interscan project by the Division of Radiophysics has already been mentioned. Other Divisions engaged in transport-related work are Building Research and Mechanical Engineering. The Division of Building Research is studying problems in transport planning and its interaction with urban and regional planning. In the rail field it has for many years assisted the railways with the development of preservatives for timber sleepers. The Divisions of Building Research and Applied Geomechanics are to be involved in a series of design studies for rail tracks being planned by the BTE and Railways of Australia. The Division of Mechanical Engineering is examining the question of fuel economy in urban road transport.

35.2.11 The Australian Road Research Board (ARRB) is the only organisation in Australia which is completely oriented towards transport research. ARRB was founded in 1960 by the National Association of State Road Authorities (NAASRA). It functions as a private company, registered in Victoria, and is controlled by a board of directors. These comprise the permanent heads of NAASRA member organisations, and the Secretary of the Commonwealth Department of Transport.

35.2.12 The bulk of ARRB's funds are provided through the Transport (Planning and Research) Act, but it also receives an input from the Department of Construction. The research activities of ARRB focus upon road and pavement design, transport planning and human factors in transport. Some of its work is delegated to research groups in the tertiary education sector. ARRB sponsors a two-yearly conference on transport research, predominantly on road matters.

35.2.13 A body similar in structure to ARRB, but focusing upon railway research, is in the process of being established. This body, named the Australian Railway Research and Development Organisation (ARRDO), will be set up as a private company in Victoria. It will be controlled by a board of directors, consisting of the State and Australian National Railway Commissioners, and the Secretary of the Commonwealth Department of Transport. Initially it will concentrate upon operational and economic matters relating to railways.

35.2.14 In the tertiary education sector there are a few institutions which specialise in transport research and its teaching. These are the School of Transportation and Traffic at the University of New South Wales, and the engineering schools at Monash University and the University of Melbourne. However, there are many sections within other tertiary institutions (usually engineering or economics departments) which have some involvement with transport. There are many links on a project basis between these institutions and government bodies.

35.2.15 Within the private sector, research activity in transport is concentrated mainly within a few large organisations. The large motor vehicle companies and related companies in the motor vehicle industry comprise a significant proportion of the total. The Broken Hill Proprietary Co Ltd (BHP) undertakes extensive research into steel technology, on

behalf of the motor vehicle and railway industries. This work is centred on its Melbourne Research Laboratories. Research on the transportation by pipeline of coal in slurry form is carried out in its Central Research Laboratories in Shortland, NSW.

35.2.16 Major companies associated with rail vehicle research are Commonwealth Engineering Pty Ltd, Commonwealth Steel Company Ltd, and the Clyde Engineering Company Ltd. Some companies have diversified their activities in response to economic trends. Hawker de Havilland Australia Ltd, traditionally associated with the aircraft industry, is engaged in small boat design. Commonwealth Aircraft Corporation Ltd is undertaking design and manufacture of bus bodies.

35.2.17 Many small and medium sized organisations are engaged in developmental work in their specific fields. Some research, mainly in transport planning, is undertaken by private consultants on behalf of government bodies. There have also been several innovations in specific areas, such as the automobile steam engine of Edward Pritchard, and a conceptual pump design for pipeline transport of coal in slurry form, being developed by a private group, B.A. Boyle and Associates. The Sarich orbital engine is now being developed with the support of BHP, in a program involving 14 professional staff and an expenditure of \$0.75million in 1976-77.

POLICIES AND AGREEMENTS

35.2.18 Recent Commonwealth Governments have encouraged an integrated approach to transport problems. In 1970 the BTE was established as the only research body in Australia to encompass all transport modes. In 1973 the two departments of Shipping and Transport, and Civil Aviation were amalgamated to form the present Department of Transport. In 1974 the Transport (Planning and Research) Act was introduced to encourage the States to co-ordinate their own programs. Recently the Government has supported moves to establish ARRDO and it is also to set up an Office of Road Safety within the Department of Transport.

35.2.19 Three formal mechanisms for liaison between the Commonwealth and State governments are described below. These are the Australian Transport Advisory Council (ATAC), the Marine and Ports Council of Australia (MPCA), and through the operations of the Transport (Planning and Research) Act 1974. While ATAC and MPCA are not themselves research forums, they exert some influence on transport research at Government level.

35.2.20 The Australian Transport Advisory Council (ATAC), which first met in 1947, comprises the State Ministers for Transport and Roads, the Ministers for the Capital Territory and the Northern Territory, and the Commonwealth Minister for Transport. The New Zealand Minister for Transport, Civil Aviation and Railways attends as an observer. The

Council advises the Commonwealth and State Governments on transport policies and seeks to co-ordinate transport development in Australia. It is backed up by four policy groups which give advice in areas such as overall transport policy, roads, railways and motor transport. A further seven technical committees make recommendations on safety in vehicle design, motor vehicle emission control, road user performance and traffic codes, publicity and road safety education, vehicle performance, transport of dangerous goods and certification of motor vehicles.

35.2.21 The Marine and Ports Council of Australia. The Council is an advisory body formed in 1976, comprising the State Ministers responsible for marine affairs and ports, the Minister for the Northern Territory and the Commonwealth Minister for Transport (as chairman). Its scope includes ports, shipping matters, cargo movements, marine laws, marine pollution and safety.

35.2.22 The Transport (Planning and Research) Act 1974 The Act was introduced to provide assistance to the States towards programs of planning and research into roads and urban public transport. For approved projects, two-thirds of the funds are provided by the Commonwealth, with the State providing the remaining one-third, and being responsible for project implementation. Activities funded under the Act include research into urban transport planning, traffic engineering, road construction, data collection, and urban railways. The new Act, which is at the drafting stage, will be extended to include research into virtually all forms of surface freight and passenger transport.

35.2.23 In 1976-77 a combined total of \$12.0million was contributed under the Act by the States and Commonwealth, although only about \$4.3million could be attributed to R&D falling within the SCORE criteria. Of this latter amount, \$2.17million was a direct contribution to ARRB and the remainder was distributed across projects within the State authorities.

35.2.24 Two mechanisms influencing relationships between the Commonwealth and private industry are discussed below. These are the Transport Industries Advisory Council (TIAC) and the Industrial R&D Incentives Act.

35.2.25 The Transport Industries Advisory Council (TIAC) comprises representatives of all modes of transport and is a mechanism for direct access between the transport industry and the Commonwealth Minister for Transport. It provides advice and information to the Minister on issues affecting the transport industry as well as making recommendations on ways to improve Australia's transport system.

35.2.26 The Industrial R&D Incentives Act 1976. Under this Act, administered by the Department of Productivity, grants are made for R&D activity undertaken by private industry. Due to the secrecy clause within this Act it was not possible to obtain direct information about the R&D activities themselves. However summaries of funding allocations under broad areas of activity were obtained and those related to transport are presented in Table 35.4. The categories of road and rail transport

primarily cover R&D into vehicles and ancillary equipment. The air category may include hovercraft, helicopters and light planes. 'Other' transport R&D mainly covers marine and small boats.

35.2.27 'Transport and Storage Containers' is listed here because this field relates directly to the materials handling industry. The final category, 'Engines', can include steam and orbital engines but not electrical machines, and this has also been included here.

35.2.28 It is important to note that until the Act was changed in 1976, grants could be made for R&D performed over a series of years prior to the grant year. Figures in Table 35.4 are thus not necessarily indicative of R&D being undertaken in any particular year.

35.2.29 In matters related to air transport, the Air Navigation Act has already been mentioned. Australia is also a member of the International Civil Aviation Organisation (ICAO) and contributes to the work of that organisation at formal meetings, by expert representation on working groups and by other activities. Except in rare circumstances Australia adopts the standards and procedures prescribed by ICAO.

35.3 THE CONDUCT OF R&D

DESCRIPTIONS OF R&D ESTABLISHMENTS

35.3.1 In the transport sector, R&D is distributed across a large number of organisations and in most cases it forms only a small part of overall activity. Since the nature of this review does not allow an exhaustive coverage of all organisations likely to be engaged in R&D, the list of establishments presented here is not comprehensive. For many of the organisations it is difficult to estimate the proportions of total funding and manpower which can be attributed to R&D, and it is emphasised that these quantities are approximate. In particular, it is not possible to cover the full spectrum of activity in the private sector. Key organisations in each sphere of activity were approached in order to achieve a balanced cross-section of the industry.

DESCRIPTION OF MAJOR R&D PROGRAMS

35.3.2 Transport in Australia has traditionally been organised according to mode, with individual organisations being given the responsibility for a particular mode. Thus each organisation has generally undertaken its research task on a single mode basis. In transport planning, greater emphasis is placed upon multi-modal factors than in other research areas and so this is discussed first. Following this the categories of road, rail,

sea, air, and then freight and materials handling, are used as a framework to structure the rest of the discussion. The relative R&D efforts across the categories are compared in Table 35.5, in terms of proportions of total funding directed to each. Clearly, road transport is the largest area of activity and for ease of treatment, road research is divided into the sub-headings: road design, road safety and road vehicle.

TABLE 35.5

APPROXIMATE PROPORTIONS OF TOTAL FUNDING IN EACH MODE

	(%)
Transport Planning	11.5
Road - design	11.0
- safety	5.5
- vehicle	51.0
Rail	8.5
Sea	1.5
Air (Operations and facilities)	6.0
Freight and Materials Handling	5.0
Total	<u>100.0%</u>

Source: Bureau of Transport Economics.

Transport Planning

35.3.4 Transport planning is a means of influencing the development of transport within the broader framework of urban and regional planning. Its scope must cover social and environmental issues as well as technical and economic factors and so it is closely linked with many other areas of activity. There is an increasing awareness of the need for integrated planning and this has encouraged research into approaches and techniques used in transport planning. It is necessary to distinguish between the planning activity itself and research into planning. Some transport planning may well have an innovative component; but in general, the planning bodies conduct very little research themselves and tend to use established techniques.

35.3.5 The CSIRO Division of Building Research directs about 5% of its effort towards transport-related work. The Commonwealth Bureau of Roads, now part of the BTE, has undertaken research into planning methodologies. The principal tertiary bodies contributing to this area are the School of Transportation and Traffic at the University of NSW, the engineering departments of Monash and Melbourne Universities and the School of Economic and Financial Studies at Macquarie University. In NSW, the Urban Transport Study Group (UTSG) is involved in examining urban public transport issues and is developing strategies for integrated planning. The UTSG is funded under the Transport (Planning and Research) Act 1974, and is controlled by the NSW Urban Transport Advisory Council (URTAC).

35.3.6 Current research into transport planning contains several areas of emphasis which have emerged largely as the result of directions chosen by individual centres of research. The main avenues for information flow are project-oriented links between bodies, research forums, and published literature. The areas of current emphasis in transport research are discussed below.

35.3.7 Australia poses some unique problems due to the relatively low density of development in the major cities, coupled with a heavy urban concentration of the population. Increasing attention is being paid to urban issues and the problems of shaping the development of cities for the future.

35.3.8 Land use and transport interaction, both at the urban and the regional levels is an area which presents complex problems. It is the subject of multi-disciplinary effort by the Division of Building Research. The School of Transportation and Traffic has made theoretical contributions in this area as part of its broad program of studies into transport.

35.3.9 The modelling of demand for transport is a second area of strong emphasis. This work has a strong theoretical and conceptual background and much of it is advanced by world standards. Attempts are being made to refine existing approaches to demand modelling, and thus increase its power as a tool to predict travel choice and commodity flow. Spatial and temporal variations in urban travel demand are being investigated at the University of Melbourne, as well as disaggregate factors in travel demand, comparisons of private and public transport, and other related studies. Macquarie University is conducting research based upon individual-choice theory. At Monash University, studies are being undertaken of the demand for urban freight and the flow of urban commodities. The Department of Transport has recently taken a co-ordinating interest in studies of urban freight as a contribution to research in this area, which is sponsored by OECD.

35.3.10 The major changes which are often needed to implement 'best' planning options involve long time spans and high capital investment. Thus there is increasing analysis of existing transport infrastructure to determine how it may best be utilised and to determine where improvements can be made at low cost. Short-term options under investigation include changes in traffic control and regulation, use of bus priority systems, and encouragement of para-transit [2]. Extensive analysis is required to determine the need for such alternatives and to predict their impact upon the existing systems.

35.3.11 A growing amount of attention is being directed towards transport-related aspects of air pollution and energy consumption. This area of research is relatively new in Australia and the initial effort is somewhat fragmented. Particular emphasis is being placed upon vehicle use in the urban situation and two general approaches have emerged. The first is to investigate engine design and fuel technology to reduce energy consumption and noxious emissions in individual vehicles. This is discussed later under the heading of road vehicle research. The second approach is

to examine the interaction between vehicle and environment to identify where improvements can be made through changes in the management of traffic, i.e. to effect improvements by controlling groups of vehicles. Organisations active in this latter area include the CSIRO Division of Mechanical Engineering and the Department of Mechanical Engineering of Melbourne University.

35.3.12 The most recent measure to combat air pollution from motor vehicles is the Australian Design Rule (ADR) 27A, a rule restricting the levels of emissions from car exhausts. The ADR 27A specification was based upon approaches used previously in the USA. The effects of its application have recently been examined at the Australian National University, in a study commissioned by the BTE. This work has indicated that greater knowledge is required of the chemical processes in smog formation and of emission criteria, before control measures such as this can be improved.

35.3.13 Research into transport pricing and regulation provides a background to transport planning and policy development. The BTE is undertaking work in this area as part of its function of providing advice to government on investment in transport. This area is also included in an ongoing program of studies into transport economics at the Departments of Economics at Queensland University and the University of NSW.

Road design

35.3.14 The construction and upkeep of roads is the responsibility of State and local governments, with financial assistance from the Commonwealth. The cost of the national highway system is met wholly by the Commonwealth Government. Thus road research in Australia is conducted largely for the benefit of the State road authorities. These bodies undertake road research themselves, and also sponsor research activity within the Australian Road Research Board (ARRB) and the universities.

35.3.15 ARRB is the leading centre for research in this field and in fact is the largest single road research organisation in Australia and S.E. Asia. It forms a focus for a co-ordinated program of research on a national and State basis. In 1976-77 it received some \$2.6million, a large portion of which was directed to road design and related topics. Current studies include: materials testing, construction methods, road geometry, bridge design, traffic engineering and human factors. It is recognised internationally for the quality of its research into the properties of bitumen.

35.3.16 To a lesser extent research programs are undertaken by each of the State road authorities, funded in part by the Commonwealth under the Transport (Planning and Research) Act 1974. They conduct research into road design and traffic engineering, and adapt the results of ARRB's work

to suit their own needs. Topics which are receiving increasing attention are the use of computers in road design and improvement in traffic management techniques. The authorities participate in certain major programs co-ordinated on a national basis through NAASRA. In 1976 a NAASRA team completed a study for ATAC of appropriate load limits for road vehicles. Currently NAASRA is developing a road inventory data bank which will be used by each authority to examine road improvement strategies. About \$0.18million was spent on this project in 1976-77.

35.3.17 Most of the universities in Australia are undertaking research into some aspect of road design or traffic engineering, and they have close ties with ARRB. Prominent amongst these is the School of Transportation and Traffic at the University of NSW, which has made special studies in pavement design and failure. The School conducts its own research program but has project links with ARRB, the NSW Department of Main Roads, the Australian Automobile Association and the Commonwealth Department of Transport. Some current research by this School into road friction is being funded by the Australian Research Grants Committee. The Department of Civil Engineering at Melbourne University is engaged in a study of driver behaviour and traffic movement at intersections.

Road safety

35.3.18 There are several Australian centres for research into road safety and associated human factors; there is good communication between them. The principal of these is the Traffic Accident Research Unit (TARU) in New South Wales. Established in 1969, it collects information on road safety matters from research both in Australia and overseas, and originates its own research and investigation programs. TARU receives the bulk of its funds from the NSW State Government, including the revenue from the personalised car number plate fund, but obtains some funds from other sources for specific projects.

35.3.19 In Victoria, the Road Safety and Traffic Authority (ROSTA) undertakes a range of safety evaluation studies. ROSTA is funded from the State vehicle registration levy. It also receives funds from the Road Safety Branch of the Commonwealth Department of Transport. Both ROSTA and TARU receive project funds through the Transport (Planning and Research) Act 1974. Other organisations participating in road safety research are Monash and Melbourne Universities, ARRB, and several private consultants who are engaged by government bodies.

35.3.20 The Commonwealth Department of Transport has taken an active role in the sponsorship of road safety research. In 1970 an Expert Group on Road Safety was formed to provide advice on safety matters and to review the road accident situation in Australia. It sponsored a number of forums and recommended that an Office of Road Safety be established within the Department to support State efforts. This suggestion is now being implemented and the existing Road Safety and Vehicle Structures Safety Branches will become part of this Office. The Road Safety Branch itself has continued to sponsor research and in 1976-77 it distributed \$0.5 million to universities, State bodies and private consultants.

35.3.21 There are three elements which form part of a road accident situation. These are the human factor, the vehicle/equipment factor and the background environment. In road safety research, consideration must be given to each of these elements and they provide a convenient framework in which to discuss present research activity.

35.3.22 The role of research into the human factor is to analyse the complex causal factors which underlie the behaviour of road users and to investigate how those factors might be controlled to reduce human loss. The Department of Psychology at Monash University is active in this area and in one study is examining the behaviour of drivers under different conditions. In another it is investigating the behaviour of children when crossing roads and their ability to make safe judgments about vehicle speeds. The State bodies are evaluating law enforcement approaches such as drink-driving penalties, and educational approaches such as publicity in schools, campaigns against drink-driving, and schemes for training drivers. Human behaviour is also related to the chances of injury through the choice of whether or not to use safety equipment such as seat belts and crash helmets. The results of legislation regarding the use of seat belts and helmets, introduced in the early 1970s, are being carefully monitored by TARU.

35.3.23 As a result of extensive research over the last few years there have been some improvements in the design of steering columns, door locks, passenger compartments and vehicle interiors that have increased the safety of passengers. Legislation to cover such features is incorporated in the Australian Design Rules for motor vehicle safety, which have to be endorsed by ATAC. These contain technical specifications for the above features, and also cover seat belts, tyres, noise and exhaust emissions. They are administered by the Commonwealth Department of Transport.

35.3.24 Progress has also been made in the setting and enforcement of quality standards for the manufacture of seat belts, child restraints and crash helmets. TARU has developed specialised facilities for the testing of many vehicle features. It acts on behalf of the Standards Association of Australia as the testing authority for all child restraints. The Royal Melbourne Institute of Technology performs the same function for crash helmets for motorcyclists. The success in reducing injury of seat belts which conform to the standard has now been clearly demonstrated by statistical evidence. The features of vehicle design which become important when seat belts are worn, for example the structural rigidity of the passenger compartment, are the subject of current studies.

35.3.25 All the research mentioned above has concentrated upon factors which operate during an accident. There are also those which influence the chance of an accident occurring, such as braking and steering systems, tyres, lights and visibility. Since they are intrinsic to the design of the vehicle they fall within the domain of the vehicle manufacturer. Although these features are continually being improved, it can be argued that safety aspects in the design of new vehicles have not always been given

sufficient priority by manufacturers generally, although there are some exceptions. Sometimes a change of model can negate previous improvements, for example, by reducing visibility to the rear, but the long term trend is one of continuing improvement. ROSTA is evaluating an Australian designed device named Checkmate, which progressively increases accelerator pedal stiffness in vehicles at higher speeds. It is hoped that this might reduce the tendency to drive at excessive speeds and hence reduce the number of serious road accidents. Some preliminary in-vehicle tests conducted by a rural transport company, Elder Smith Goldsbrough Mort Ltd, have shown encouraging results.

35.3.26 Road design and layout are also directly-contributing factors in accidents. Thus safety matters must be included as part of the overall research program of road authorities, and in this they are supported by ARRB. ARRB conducts and also sponsors research into conspicuity of roadside objects, the perception and recognition of signs by drivers, speed limits and design of intersections. The Department of Mechanical Engineering at Melbourne University conducts a strong program of research sponsored by ARRB and the Commonwealth Department of Transport, involving some \$90,000 in funding each year. Its scope includes investigations of the influence of road design upon the behaviour of drivers and analysis of the location of road furniture [3].

35.3.27 There are many difficulties in developing measures to control the behavioural element in accidents and so greater priority is being placed upon making the traffic system more compatible with known human limitations. This shift in emphasis from behaviour control to traffic management is increasing the importance of research into environmental factors.

35.3.28 To support research into specific aspects of road safety there is a general need for background data. Several studies of large numbers of accidents in city areas have recently been undertaken by the State bodies and it is hoped that analysis of these will provide more information on factors which contribute to accidents and enable clear priorities for research effort to be established. A study of accidents in Adelaide is being undertaken at the University of Adelaide with funds supplied by the Road Safety Branch of the Commonwealth Department of Transport. The data obtained from this study will be compared to those from a similar study undertaken in the late 1960s.

Road vehicle

35.3.29 R&D in road vehicle technology constitutes the largest component of all the categories of activity within the transport sector. The level of funding in 1976-77 is estimated at \$13million which represents 50% of the total expenditure on transport R&D (Table 35.5). The greater proportion of this amount stems from the motor vehicle industry.

35.3.30 The motor vehicle manufacturing and component industry in Australia is dominated by the large motor companies. Chrysler Australia Ltd, Ford Motor Company of Australia Ltd and General Motors-Holden's Ltd

all maintain extensive research and testing facilities. All of these companies are connected with multinational organisations and it is not surprising that their research programs are influenced by the trend towards increasing commonality in design across the world. Local R&D is heavily weighted towards the implementation of ideas from overseas and the adaption of products to suit local conditions.

35.3.31 Outside the motor vehicle industry several smaller organisations, universities and individuals are contributing to this field through self-initiated research or projects undertaken for the industry. These are described in the paragraphs below, in which the main areas of current research are highlighted.

35.3.32 In the motor industry there is a continuing incentive to improve vehicle handling, power and fuel economy, and to find cheaper manufacturing processes. Advances are being made by finding wider applications for such materials as aluminium, plastics and high strength steels. Less reliance is being placed upon traditional materials like cast iron. There is a growing use of aluminium casting for engine and transmission components. However, innovation is constrained by the need to utilise fully existing capital equipment, and the limited home market for products means that frequent re-investment in capital equipment cannot be justified. In 1976-77, Repco Ltd, a major component manufacturer, spent some \$3.0million on research and development within its group of companies. About \$1.0million of this was directed to its central research facility, Repco Research Pty Ltd.

35.3.33 The Broken Hill Proprietary Co Ltd and John Lysaght (Australia) Pty Ltd are conducting a program of research into the production of steels with a high yield strength for the automotive industry. Results equal to world standards in properties of steels have been achieved. The majority of steels required for automotive manufacture are now produced in Australia, although some steels for special needs have to be imported.

35.3.34 Olympic Tyre and Rubber Co Pty Ltd maintains a strong R&D program for the development of tyres and related aspects of manufacture. This work is funded internally, but with some assistance through grants from the Industrial R&D Incentives Act. Their program involves 30 professional staff and, in 1976-77, some \$1.17million was spent.

35.3.35 The need to remain competitive in fuel economy and to comply with legislative restrictions on emissions is stimulating research effort into engine design and combustion technology. The most recent legislation on emissions from cars, Australian Design Rule 27A, became effective on 1 July 1976. To comply with this rule the industry generally has adopted engine re-tuning measures in the short term. Operational evidence since then is showing that the emission standard is being met at the expense of fuel economy and engine performance. In the long term, this situation may be improved by engine development.

35.3.36 This trade-off between fuel economy and emission levels is being tackled in various ways. The Department of Mechanical Engineering at Melbourne University is examining fundamental combustion technology with the aim of improving engine design. The Royal Melbourne Institute of Technology (RMIT) is studying the application of ultrasonic atomisers to improving fuel-air mixtures. Fuel injection systems are also being assessed by several companies. Repco Ltd, in particular, has developed one such system.

35.3.37 Despite research into the technology of combustion in the traditional petrol engine, it appears that only limited improvements may be made. The gains made in changing from, say, a large heavy vehicle to a relatively smaller and lighter one are much greater than the marginal improvements which can be made in the design of a given engine. It is apparent that there is insufficient research into alternatives to the traditional petrol engine, and that there will be no single solution to this general problem.

35.3.38 Several systems which are not based on the traditional reciprocating petrol engine are being investigated, primarily by groups outside the motor vehicle industry itself. An orbital engine, invented by Ralph Sarich, is now being developed further by Orbital Developments Ltd, with the support of BHP. It is possible that the stage of development for production may be reached within two years. The gas turbine engine is a further option to be considered. Such engines have already been fitted to large commercial trucks, but have not been successfully applied to small vehicles. The feasibility of the application of ceramic materials to gas turbines for motor vehicles is being examined at the Royal Melbourne Institute of Technology.

35.3.39 Development work on a steam-powered car has been undertaken over a number of years by Edward Pritchard of Pritchard Steam Power Pty Ltd. The project, including the production of several prototype engines at the Bendigo Ordnance Factory, has cost \$0.4million. A recent special State/Commonwealth grant has helped and it is hoped to bring the engine to final development within eighteen months. To date the engine appears to be equal in performance to similar developments overseas. Some testing of steam vehicles has also been undertaken by the State Department of Transport in South Australia, funded through the Transport (Planning and Research) Act 1974.

35.3.40 Finally, electric vehicles are being developed by at least two groups in Australia. At Flinders University in South Australia, a research team has developed a prototype electric car. Funds for this project have been obtained from a number of sources, and include a grant of \$80,000 in 1976-77 from the Commonwealth and South Australian Governments through the Transport (Planning and Research) Act 1974. An electric urban bus has been developed to an experimental stage by a private consultant, L. Roy Leembruggen, and interest in this project has been shown by authorities in several countries. Some research on electric vehicles is also being undertaken by the large motor vehicle companies, and the CSIRO Division of Mineral Chemistry has a program of assessment and development of high energy-density battery systems.

35.3.41 Some knowledge of electric propulsion also exists in other areas. In the early 1970s, working models of a battery-powered motor for a small urban car were constructed at the University of NSW. At the School of Electrical Engineering of the NSW Institute of Technology, a model of a linear induction motor was developed. This would power a rapid-transit rail system for a city. This latter project has been assisted by the Australian Research Grants Committee. The economic viability of electric vehicles such as these is not yet established, but they have a potential role in urban transport where their use is favoured by zero emission, low noise characteristics, and the relief they offer to depletion of oil stocks. The performance of electric vehicles is limited by the capabilities of the battery. At present their development is largely dependent upon a breakthrough in battery technology.

35.3.42 A system in which Commonwealth Aircraft Corporation Ltd has expressed interest, involves the use of both electric and internal combustion motors in vehicles such as buses. In concept, batteries would provide power under cruise conditions with the internal combustion engine being used for acceleration.

35.3.43 Improvements in transport technology and efforts to reduce costs necessarily encourage the development of new manufacturing methods, most of which are geared to the use of new materials and design techniques. A method of fastening metals in which component distortion is greatly reduced, is an example of such a process. This technique is being patented by Commonwealth Aircraft Corporation Ltd. Other examples found in the motor industry are electrostatic surface coating and advanced welding techniques.

35.3.44 In the above paragraphs the main areas of current research on motor vehicles have been highlighted. The contribution to this research from industry has generally been aimed at product development along established lines. The investigation of new forms of transport has largely been undertaken by small centres of activity. Although road vehicle research absorbs a large part of the total R&D funding in transport, the proportion which it represents does not give a true indication of its innovative value.

35.3.45 There is a need to investigate new forms of transportation suited to our operating environment and there are two areas in particular which should receive greater attention. The first is investigation of propulsion systems which may become viable alternatives to traditional internal combustion engines. The second is research into vehicles to perform urban transport tasks in the future. The resources needed to support this type of research are large and it is not sufficient to expect it to be maintained by small isolated centres.

Rail

35.3.46 In Australia each of the States has been responsible for the operation of its own railway system with the Commonwealth Government (ANR) operating the central portion of the trans-Australia link, the

central Australian railway to Alice Springs, and, recently, the regional network in South Australia. As well, there are several private railways in Australia, notably four in the Pilbara region of Western Australia, operated by mining companies. There is also a network of lines for the transport of sugar cane on the coastal plains of Northern NSW and of Queensland.

35.3.47 The State systems are characterised by long distances between major centres over which moderate traffic levels are maintained. This is a different framework for application of R&D to that of the major overseas networks where research is directed towards heavy traffic and high speeds. In the past, State rail authorities have failed to see the value of a central body equivalent to the Australian Road Research Board to conduct rail research. Instead, R&D has been undertaken usually as a small part of the activities of the operating authorities in the States. It has been fragmented and resources devoted to it have been limited, by comparison with road research.

35.3.48 By contrast to the State networks, the private mining systems operate a frequent, one-way traffic of heavy mineral trains. The combination of high axle loads and adverse environmental conditions places a severe burden upon track and vehicle. The mining companies in the Pilbara are sponsoring a great deal of research into the design and operation of high axle load systems and Australia has achieved world eminence in this field.

35.3.49 Railway R&D which falls within the criteria of this review, accounted for some \$2.1million in 1976-77 or about 8.5% of total funding over all modes. This figure includes R&D sponsored by both government and private sources. Of this amount about \$0.63million was directed to work performed by the Melbourne Research Laboratories of the Broken Hill Proprietary Co Ltd (BHP). This is by far the largest single area of activity in rail research. BHP has been conducting a program of studies into rail vehicles and track, in conjunction with government bodies, universities and private industry. The main sources of this funding are the mining companies in the Pilbara.

35.3.50 The State rail authorities each conduct research and planning programs aimed at maintaining and improving networks within their resource limitations. Railways of Australia (ROA) is a joint body comprising a secretariat and working committees, with representation from all the State systems and ANR. ROA is a medium for participation in joint R&D activity and although in the past such activity has been limited, there is a recent trend towards more intersystem programs. The States are eligible for Commonwealth funding under the Transport (Planning and Research) Act 1974 for research into urban rail, although rail projects under the Act have so far constituted only a small part of overall activity by State authorities.

35.3.51 The Bureau of Transport Economics has been associated with economic and pricing aspects of rail systems and has developed close links with the States. It has undertaken evaluation studies into freight operations and the upgrading of the intersystem rail links. Currently it is

planning to sponsor a program of studies with ROA, BHP and CSIRO into track design to minimise ultimate costs and into vehicle-track interaction. These studies will be controlled by Westrail.

35.3.52 R&D activities for railways are discussed below in terms of rail vehicle, rail track and rail operations. The dynamic interaction of vehicle and track is an aspect which is receiving particular attention and is treated separately. Developments in urban rail are discussed. These are the main categories of research work, although there is much more planning and development work, not discussed here, which falls into the general area of system improvement.

35.3.53 Innovation and change have generally not been rapid in the design of rail locomotives and rolling stock. Rail vehicles have been expected to last for periods of up to 50 years. However there is a movement towards the improvement of rolling stock design. A recent initiative has been towards the modular construction of carriages, and organisations such as Commonwealth Aircraft Corporation Ltd are investigating the use of aluminium alloys in place of the more expensive stainless steel. The use of high phosphorus brake blocks, in place of the traditional cast iron, for fast trains is being studied by Victorian Railways. The NSW Public Transport Commission is improving methods for testing wheels for rolling stock.

35.3.54 The main emphasis in rail vehicle innovation has been directed towards the development of new bogies for both passenger and heavy freight use. This is an area in which there is considerable scope for improvement. Research into a lightweight fabricated bogie for suburban rail cars has been commenced by Commonwealth Engineering (NSW) Pty Ltd, with the objective of attaining greatly increased passenger comfort as well as lower maintenance costs. A new bogie for use on heavy ore waggons has been developed and produced by Commonwealth Steel Company Ltd, and is claimed to display marked superiority in riding quality, thus reducing track and rail wear. The 2CM bogie, a fast freight bogie, has been designed and developed by the NSW Public Transport Commission in conjunction with the Commonwealth Steel Company. It represents a departure from the traditional three-piece bogie, and displays greatly improved operating characteristics although its unit cost is greater.

35.3.55 Track design has received the main thrust of rail research, due largely to the efforts of the Pilbara iron ore companies which need improved tracks to carry the heavy ore trains. A series of studies is being undertaken on their behalf by BHP to examine patterns of wear and failure of rail under heavy loads, and the associated risks of derailment. A related program is the development by BHP of a range of alloy steels for heavy load conditions, and some world pre-eminence can be claimed in this field. Steel sleepers are also being designed and tested by BHP to provide a range of sleepers for different expected axle load conditions. Although the above programs are directed towards the mining rail systems they can be expected to provide a spin-off for State rail systems, where a trend towards increased axle loads and higher train speeds is evident in general freight operations. Work in this direction has been initiated at the BHP Melbourne Research Laboratories by the Bureau of Transport Economics.

35.3.56 The CSIRO Division of Building Research has, for many years, undertaken research into preservatives for the hardwoods used in timber railway sleepers. In this work it has assisted railway authorities in all States by initiating service trials and setting up treatment plants.

35.3.57 Present knowledge of the dynamic interaction between rail track and loaded vehicles is limited. There are large benefits to be gained by increasing this knowledge since wheel, rail and track deterioration can be reduced, thus lowering maintenance costs and allowing operating speeds to be increased. Studies in this field are being undertaken by BHP on behalf of the mining companies. This is also under study in several other organisations, including Commonwealth Engineering Pty Ltd and the Universities of Adelaide, Newcastle, and Western Australia. Further, a series of track-train studies have been initiated by the BTE in conjunction with ROA and CSIRO, in which, initially, a number of test sections will be included in a track to be upgraded, and their behaviour monitored. The studies will be controlled by Westrail. The CSIRO Division of Building Research will take an interest in the sleepers and fastenings, and the Division of Applied Geomechanics will be involved with soil mechanics and foundation aspects. BHP will provide expertise on track design and track-train dynamics.

35.3.58 Problems in the control of very long coal trains have been studied by Queensland Rail, who have developed a system to allow more flexible use of locomotives in multiple groups. The system is a modification of Locotrol, a device previously patented by Harris Controls in the USA. Locotrol can be fitted to a remote locomotive group in long trains, allowing it to be controlled by the driver in a leader group. The Queensland modification allows two different types of locomotive to be used in the leader and remote groups. The Sugar Research Institute, Queensland, has developed a similar system for use on sugar cane transporting trains.

35.3.59 The improvement of signals and telecommunications for system control is being undertaken by all State systems, although this is accomplished generally by the importation of overseas technology as a 'package', which requires a minimal amount of local adaptation.

35.3.60 The BTE has been prominent in defining methodologies for the evaluation of operations and investment decisions in rail systems. In the Engineering Department of James Cook University, a systems analysis approach is being used to study the efficiency of operations of trains used for carrying sugar cane.

35.3.61 Research into urban rail is eligible for funding under the Transport (Planning and Research) Act 1974. Projects funded under the Act to date have been directed towards continuing technical and operational improvements without an appreciable degree of innovation and there is a general tendency to use 'off the shelf' imported technical equipment. An electrification program has been commenced on some sections of the urban system in Brisbane and again the operating system has been designed overseas. The concept of an Australian Urban Passenger Train (AUPT) was originally proposed by the Commonwealth Department of

Transport. The concept was that of an advanced urban train providing a high level of passenger comfort and with a basic design standardised sufficiently to fit into existing urban networks. This has led to studies into interior designs by a private organisation, Hawker de Havilland Pty Ltd, and the AUPT specification has been incorporated into recent tenders for urban rail cars by Queensland Rail. Recently, activity on the AUPT project has been limited.

35.3.62 Rail research in general is fragmented and there is insufficient exchange of information between organisations. The State systems in particular have found difficulty in keeping up with advances overseas, largely because there has been no central organisation to receive and disseminate information. However, a recent report on railway R&D prepared by ROA has shown that there is an increase in joint research programs under the co-ordination of ROA, although there are problems associated with the control of funding. The problem of insufficient information exchange has also been recognised. The States are aware of the possible long-term value of attracting Commonwealth co-ordinated funding for their research and planning activities.

35.3.63 The formation of ARRDO should ease some of these problems, particularly the collection and dissemination of information. It will take some years for ARRDO to develop fully its planned role which is limited to research in economic and operational matters. It will not perform a technical research role. Technical research will therefore have to be continued by the State authorities and private industry and it may be that these bodies will develop their future activities to complement those of ARRDO. It would be desirable for ARRDO to develop a role parallel to that of ARRB, and to encourage research within the universities and rail authorities as well as undertaking research itself.

Sea

35.3.64 In recent years there has been a decline in shipbuilding activity in Australia and a corresponding reduction of investment in shipbuilding facilities. Relative cost disadvantages have meant that shipbuilders have been unable to compete on the world market, and government subsidies to the industry have been progressively reduced over a period of years. Against this background there has been a decline in R&D related to ship design. Present R&D represents only about 1.5% of the total in transport and this is directed mainly towards small vessels and operational aspects of shipping.

35.3.65 The Government Shipbuilding Division is at present located within the Department of Industry and Commerce. It possesses a central design office staffed by hull, machinery and electrical designers able to undertake new design and development work. At present the office is engaged mainly in examining existing shipping operations to identify where cost savings can be made, and is acting in a consulting role on minor design matters.

35.3.66 In previous years the Division has undertaken extensive tank testing of ship models to create a data bank of performance characteristics. It has investigated heavy duty turbo-electric propulsion for bulk carriers and the design of roll-on roll-off (RO-RO) cargo vessels. The RO-RO concept in particular caused one of the most significant changes in ship design, and has now become established in operational use.

35.3.67 The Australian Shipbuilding Board was established in 1941 and now functions as a board of advice to the Minister for Industry and Commerce on shipbuilding matters.

35.3.68 The Marine Standards Division of the Commonwealth Department of Transport is responsible for formulating and implementing safety and other standards. Its past research programs have included seaworthiness of small craft, storage of dangerous cargo, and ferro-concrete hulls for small vessels. It is investigating the provision of shore-based waste reception facilities as a means of preventing the control of pollution from ships. Future research may include fire protection in boats and the use of glass reinforced plastic in the design of hulls. The Marine and Ports Council of Australia (MPCA) provides a communication channel between the Minister for Transport and the States, concerning ports, shipping, marine pollution and safety. The question of port development is one in which the Bureau of Transport Economics has played an evaluation role. A simulation model of port operations in Townsville has been developed by James Cook University and is being used to predict how the port facilities will cope with future demand.

35.3.69 The Department of Defence (Navy Office) maintains research capacity in Canberra and elsewhere although very little of this is directed to topics in the civilian sector. Defence experimental establishments, particularly the Aeronautical Research Laboratories, have, however, been used by the Shipbuilding Division.

35.3.70 In the tertiary education sector there is some fragmented research interest in the marine area, and this chiefly exists in the engineering and economics/commerce disciplines. The Department of Mechanical Engineering at the University of NSW is a centre of theoretical and experimental research in ship design. It has undertaken research projects in conjunction with the Shipbuilding Division and the Department of Defence.

35.3.71 In the industry itself, some research is being conducted into the design of small vessels, by companies such as Hawker de Havilland Australia Pty Ltd. Total research effort is difficult to estimate, but \$49,000 was provided through the Industrial Research and Development Incentives Act in 1976-77 towards this general area. The main directions of current research are to reduce production costs and improve safety qualities.

35.3.72 The depressed nature of the shipbuilding industry raises questions concerning the direction which R&D should take. The need has

been voiced for a marine research council to review developments in Australia and overseas and to identify those which can be of greatest local benefit. If such a council is to provide a broad coverage it must contain representation from shipbuilders, shippers and designers as well as government. This would raise problems of funding and control of such an organisation. But it would provide an important focus for research activity in Australia and for the collection and dissemination of information.

Air

35.3.73 This section covers R&D into air operations and facilities in the civilian sector. Topics relating specifically to military use are not included, and the field of aircraft structural design and manufacture is discussed in Chapter 25, 'Aeronautics and Aerospace'.

35.3.74 The Commonwealth provides major aerodromes and all airway facilities for international air services, and the Department of Transport is the central focus of R&D into air operations and facilities in Australia. The Department allocated some \$1.3million in R&D funding in 1976-77. Of this amount, CSIRO received \$0.25million for its research towards Interscan, (and contributed \$0.23million of its own funds) and \$0.15million was allocated to the Air Navigation Group which is maintained within the Electrical Engineering Department of the University of Sydney by the Department of Transport. The remainder was used to fund activities of the Department itself or of private industry on a contract basis.

35.3.75 The Air Navigation Group has existed since 1965 and at present comprises five professionals and two other staff, headed by a senior research fellow. Its salaries and activities are funded entirely by the Department of Transport. The direction of its research is controlled by the Department and it has been closely involved with the Interscan project. Current R&D in air operations and facilities is described below.

35.3.76 The major thrust of recent R&D effort in air transport has been towards the development of Interscan, a new, non-visual, approach and landing guidance system for civil aviation. The Interscan project has continued since 1972 and is now well advanced. It commenced in response to a request by the International Civil Aviation Organisation (ICAO) for proposals. Australia and four other member countries responded and the USA adopted critical major aspects of the Australian system. The Australian-USA proposals were recommended by a specialist technical assessment panel of ICAO and were adopted as an international standard in April 1978. The Department of Productivity carries administrative responsibility for Interscan and has participated, together with the Department of Transport, the Air Navigation Group and Amalgamated Wireless (Australasia) Ltd, in its development and testing. Basic research leading to the development of the concepts on which Interscan operates was conducted by the CSIRO Division of Radiophysics.

35.3.77 The Department undertakes R&D aimed at improving the performance and cost effectiveness of message switching facilities, and HF,

VHF and UHF communications systems. In collaboration with industry, non-directional beacons are being improved as navigational aids. The Air Navigation Group in Sydney University is studying methods of processing primary radar signals and methods of improving antennae systems for the glide paths used in instrument landings.

35.3.78 This area involves the provision of interface facilities between Air Traffic Controllers and the communications, surveillance and navigation systems at their disposal. R&D is conducted to adapt technology as it becomes available and to improve the cost effectiveness of existing facilities.

35.3.79 There is a continuing drive to develop new solutions of the technical problems of airport engineering. Studies are also being undertaken to prescribe standards for Australia-wide application. These include design procedures for pavement works, rubber removal, non-destructive strength testing and prevention of aquaplaning.

Freight and materials handling

35.3.80 Materials handling systems are employed in all sections of industry and they perform a wide variety of roles. This makes it difficult to define rigidly the overlap of this field with the transport sector. For this section, however, its scope is taken to include freight and materials handling activities which operate as an interface between transport modes, or which can be readily identified as 'transport' operations themselves. Specialised facilities for handling materials in the industries covered by other Chapters are not mentioned here and demarcation boundaries for these are summarised in the notes [1].

35.3.81 R&D in this field is conducted primarily by private industry. Design and system improvements are undertaken by many industrial organisations which control their own handling operations, as well as by the manufacturers of systems for handling materials.

35.3.82 There is little R&D in the government sector generally, but the Commonwealth Government provides an important focus of research for all sectors in the form of the Materials Handling Bureau (MHB). The MHB previously formed part of the Bureau of Transport Economics but is now located within the Department of Productivity. Its research work is mainly project-oriented and close links with industry have been established. It is also concerned with national standards and regulations.

35.3.83 Design work in this field is also undertaken by private consultants. Some links concerning equipment design and technology exist between industry and the universities, although no current R&D in the tertiary education sector has been identified.

35.3.84 Total funding directed to materials handling research is estimated at \$1.25million or 5% of the total 1976-77 allocation for research in the transport industry. This estimate is expected to be conservative because of the difficulties of covering this field adequately, although much of the

activity is not sufficiently innovative to satisfy the R&D criteria used here. Of the above amount, \$0.12million was contributed under the Industrial R&D Incentives Act 1976. It is represented in Table 35.4 under 'Transport and Storage Containers'.

35.3.85 The main emphases of current R&D are to reduce costs in materials handling operations by improving their efficiency, and to remain competitive in the manufacture of handling equipment. This latter problem is being tackled by improvements in manufacturing to reduce costs and by an increasing use of 'high technology'. The main areas of current research are summarised below.

35.3.86 The MHB figures prominently in this area of activity. Its R&D program is directed towards improvement of packages and containers for goods in transit; five professionals are employed in this field on a full-time basis. Examples of current projects are the investigation of the surge of liquids in tanks during transit and the scuffing damage to empty glass containers. The MHB provides testing procedures for a variety of packages. It will be examining transport environments in Australia so that more effective laboratory simulation methods can be developed.

35.3.87 In the container industry there is a move to utilise new materials with improved properties, and to incorporate low cost/high technology into design philosophies. By way of illustration, two projects are cited from current research by Freighter Franklin Ltd. The first is to develop a convertible steel container with options such as removable refrigeration linings. The second is to investigate the use of aluminium in trailer design. In the latter, the potential advantage is to reduce weight without reducing overall strength, but there are design problems of stress capacity and steel/aluminium abrasion to be overcome. John Lysaght (Australia) Ltd is an example of a large manufacturing company which operates product shipment and materials handling systems. It develops and tests its own packages and maintains contact with the railway authorities concerning modification of rail wagons to carry its products. Through its research facilities it is investigating problems of abrasive wear to steel coil products during road shipment.

35.3.88 The need to reduce loading time between transport modes has stimulated the development of more efficient handling systems. The most significant change in recent years has been in ship-to-shore cargo handling facilities. In conformity with world trends, ports in Australia have introduced containerisation, and roll-on roll-off cargo vessels have been built. The Australian National Line (ANL) conducts ongoing assessment and development of techniques such as these. Also, operational research techniques are being increasingly employed in studies of the efficiency of systems. An example is provided by John Lysaght (Australia) Ltd, which is using computer simulation and modelling to aid the design of a new shore-to-ship handling system for steel slabs.

35.3.89 Attempts to improve the interface between road and rail have brought developments such as rail flexivans, and road semi-trailers whose loads can be lifted directly onto rail wagons. However, such vehicles have

proved to be expensive and there is wide scope for lower cost solutions to these problems.

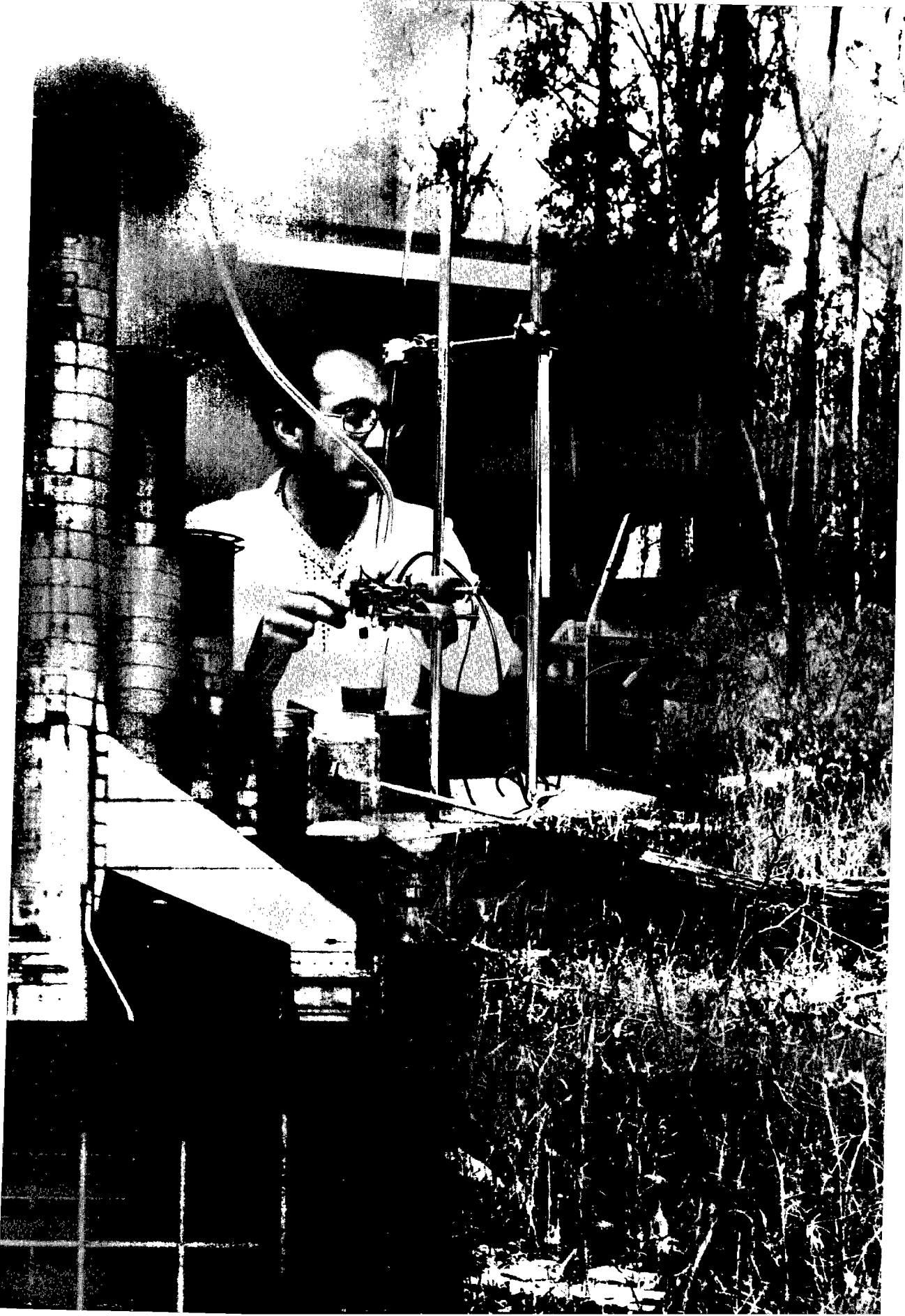
35.3.90 The pipeline transport of coal and other solids, either as slurries or as discrete lumps, is a development which may prove to be an effective alternative to road and rail transport in certain situations. Development work on a pump to handle coking and steaming coal in a slurry has been undertaken over the past few years by a private consulting group, B.A. Boyle and Associates. If the pump design lives up to its early promise then the slurry transport method, which has advantages in terms of capital and operating costs, may find use in many industries. It would then place Australia in the forefront of world development of this type of application.

35.3.91 The BHP Central Research Laboratories at Shortland, NSW, are conducting an extensive program of research into the transport of coal slurry by pipeline. An experimental pipeline loop is being operated to determine any detrimental effects on coking properties of coal transported by pipeline, and to establish engineering parameters for the design of a commercial pipeline system for coking coal.

35.3.92 The materials handling industry is closely tied to general industrial activity and the direction of its research is influenced strongly by general trends. In particular the recent low levels of capital investment in many areas have shifted the emphasis of R&D towards shorter term development of existing systems. This, and the increasing use of overseas 'packaged' technology have contributed to a decline in the more innovative aspects of Australian R&D in this field.

NOTES AND REFERENCES

1. This Chapter does not cover any technical aspects of aeronautics and aerospace as these areas are included in Chapter 25. However, air operations and facilities in the civilian sector fall into this review. It does not discuss the development and production of fuels for the transport industry. However, energy consumption aspects of vehicle design or transport regulation are included here. R&D into the creation of transport infrastructure is included here if it is being performed by or on behalf of a transport organisation. This essentially includes the State road, rail and port authorities, and their operations. The planning of urban and regional land use is closely linked to transportation planning. Activity here is included where it is being performed by or in conjunction with a transport body, or where it directly impinges on transport functions. Activity in materials handling is included where it can be identified as a transport activity. Specialised applications in other review areas such as agriculture, mining, metal products, construction and forestry are not discussed here. The defence sector has not been isolated as a separate review category by ASTEC, and R&D activity within defence establishments is included here if it may have a spin-off into the civilian transport sector.
2. Para-transit is a term used to describe collectively forms of transport in which the traditional modes have been modified to provide a specialised service, e.g. dial-a-bus, car-pooling, bus priority lanes.
3. Road furniture is equipment such as signs, lights and poles used to control traffic or as an aid to the driver.



Photograph: A composite photograph illustrating the environment, influences on it, and scientific activity which monitors and attempts to alleviate adverse environmental impacts.

(Photograph courtesy Griffith University).

CHAPTER 36

ENVIRONMENT

36.1 BACKGROUND

GENERAL

36.1.1 Environmental issues are concerned with a very broad range of man's activities. They embrace many disciplines. The management of the environment depends on a complex series of interactions between specialists from different disciplines and administrators operating in government, industry and tertiary institutions.

DEFINITION OF AREA COVERED

36.1.2 This Chapter attempts to cover the infra-structure and policies of environmental R&D in Australia and to describe briefly some of the environmental R&D programs. However, because of the large overlap between environmental studies and activities in other more specific areas, it is often difficult to separate environmental R&D from work that is highly relevant to (and discussed in) other chapters of this Report. This chapter therefore concentrates on studies (largely physical as opposed to social) aimed at providing a basis for policy formulation related to pollution control, conservation and resource management.

36.1.3 An Appendix is included which covers an area of activity that cannot be readily incorporated into the structure of this chapter. Appendix 36.1 deals with 'Mining Reclamation', and links this chapter and Chapter 24 ('Mining Engineering and Mineral Processing').

36.2 ORGANISATION

BACKGROUND

36.2.1 A number of ad hoc activities having environmental significance can be traced back to Federation and earlier, but the development of explicit environmental policies in Australia did not occur until the 1970s, and then mainly following overseas activities which were widely publicised. Teaching and research in environmental areas have also received

considerable stimulus from overseas activity. Today the amount of research and development on environmental issues in Australia is quite small compared with that carried out in other developed countries. While the maintenance of effective contact with overseas workers has been valuable, and continues to be so, the character of many environmental problems requires indigenous recognition, research, policy development and implementation because Australia's climate, ecological systems, flora and fauna, and the concentration of pollutants and the capacity of systems to absorb these are not the same as those of other countries. In addition, legislative, administrative, political and economic differences may require different methods of environmental protection and control.

36.2.2 Environmental responsibilities are not mentioned in the Federal Constitution as the concept of environmental responsibilities had little currency at the time. The seriousness of an environmental problem is dependent on the local systems and so it is not a matter which is readily centralised. Currently both Commonwealth and State governments have significant environmental roles. In general, the prescription and enforcement of allowable emissions, effluents and noise and of other environmental matters are a State responsibility and, consequently, pollution standards are not uniform throughout Australia. While the need for uniformity is a debatable matter, the need for the co-ordination of research to derive standards is generally accepted. Such research needs to take account of technical, economic and environmental factors.

COMMONWEALTH GOVERNMENT

International activity

36.2.3 The Government participates in the Organisation for Economic Co-operation and Development (OECD) environmental policy and research activities - in particular, the Department of Environment, Housing and Community Development (EHCD) works with the OECD Environment Committee, and the Australian Atomic Energy Commission (AAEC) with the Nuclear Energy Agency of OECD. The Commonwealth Government also has significant links with the United Nations Environment Program (UNEP). There is participation of Australian research teams in UNEP and in the UNESCO-sponsored 'Man and the Biosphere' projects. There are environmental aspects to our participation in the International Nuclear Fuel Cycle Evaluation (INFCE) program. Through such participation, Australia plays a role in the development of international environmental policies, and also derives benefit from access to international information of environmental significance.

Environment, Housing and Community Development (EHCD) Ministry

36.2.4 EHCD is responsible for developing, co-ordinating and implementing policies and administering programs on matters of national environmental significance. Figure 36.1 gives the relationship of EHCD to other Commonwealth bodies and indicates the statutory authorities

responsible to the Minister for EHCD. Under the provisions of the Environment Protection (Impact of Proposals) Act 1974 (and the Environment Protection Administrative Procedures made under the Act) proposals involving Commonwealth decisions or funding are subject to an examination of an Environmental Impact Statement (EIS), and possible public review, when the environment may be affected to a significant extent.

36.2.5 Three statutory authorities responsible to the Minister for EHCD, all concerned with conservation policies and having varying degrees of research responsibilities, were established in 1976-77 :

- . Australian Heritage Commission
- . Australian National Parks and Wildlife Service
- . Great Barrier Reef Marine Park Authority

In addition, in June 1978, the office of the Supervising Scientist for the Alligator Rivers' Region was created for the purpose of protecting that region from any deleterious effects of uranium mining operations. An Australian Ionising Radiation Advisory Committee (AIRAC) which is advisory to the Minister for EHCD, has also been established. The membership includes experts having a wide range of scientific disciplines.

Science Ministry

36.2.6 The Australian Institute of Marine Science (AIMS) is located near Townsville and carries out marine research and enters into co-operative programs with other institutions.

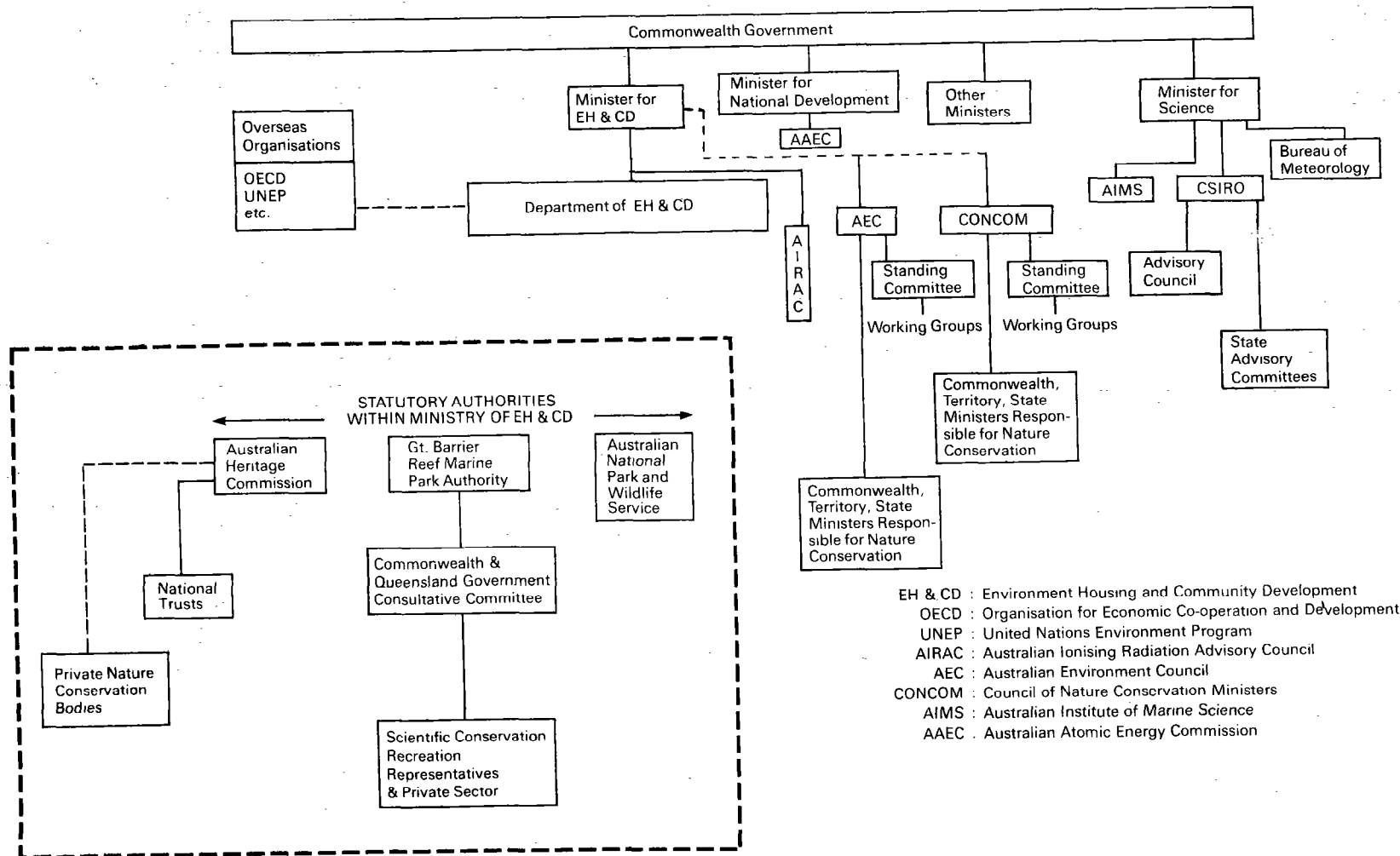
36.2.7 More than half of the Divisions of CSIRO undertake research of environmental significance, including the Divisions of Land Use Research, Land Resources Management, Soils, Atmospheric Physics, Cloud Physics, Environmental Mechanics, Wildlife Research, Plant Industry, Forest Research, Entomology, Building Research, Chemical Technology and the Minerals Research Laboratories. The major emphasis is in the physical and biological sciences. A small number of social scientists (most of them economists) are employed where research has significant social dimensions.

National Development Ministry

36.2.8 The policy of the AAEC from its inception has involved support for a variety of research programs on the impact of radiation on man and the environment. While the emphasis has varied over time with particular needs, current programs emphasise the environmental problems associated with the uranium mining and milling industry.

36.2.9 The Department of National Development has responsibility for work on national water resources, including assessment and research. Energy conservation and soil conservation responsibilities are also important environmental elements of the work of that Department.

FIGURE 36.1
STRUCTURE OF COMMONWEALTH GOVERNMENT ORGANISATIONS AND INTERGOVERNMENTAL RESEARCH AND DEVELOPMENT



Other Ministries

36.2.10 The Environment Protection (Impact of Proposals) Act (1974) gives all Ministers an environmental role, in that they are required to take environmental factors into account in their decision-making, and if those factors are significant to follow the Environmental Impact Statement procedures.

36.2.11 In addition, some Ministers have more specific environmental responsibilities. The Department of Primary Industry, for example, through its association with the Australian Agricultural Council and the Standing Committee on Agriculture, serves as a central authority for Australian activities associated with the use of agricultural and veterinary chemicals. The Standing Committee on Agriculture's Co-ordinating Committee on Agricultural Chemicals, and its three subsidiary committees, review and advise on the overall problems of the use, or potential use, of agricultural and veterinary chemicals including their effect on the environment. The Department of Primary Industry conducts a continuous and extensive survey of chemical residues in primary produce and advises State authorities on any necessary action. In addition, the Department of Primary Industry has soil conservation responsibilities through the Standing Committee on Soil Conservation.

36.2.12 The Department of the Capital Territory has responsibility for the environment and for conservation within the ACT through its Conservation and Agriculture Branch. This Branch has some research capacity in wildlife conservation, and in some studies it collaborates with the National Capital Development Commission (NCDC) which is responsible for ACT planning.

COMMONWEALTH-STATE COUNCILS

36.2.13 Two important inter-governmental bodies have been established to help implement and reinforce the collaborative policy of the Commonwealth Government in environmental matters. These are the Australian Environment Council (AEC) and the Council of Nature Conservation Ministers (CONCOM). There are other Commonwealth-State Ministerial Councils that have specific environmental responsibilities; these include the Australian Agricultural Council (see 36.2.11) and the Australian Transport Advisory Council, which advises on motor vehicle emission control (see Chapter 35, 'Transport').

The Australian Environment Council (AEC)

36.2.14 The AEC comprises the Commonwealth, State and Territory Ministers with prime responsibility for environmental matters. It deals especially with environmental matters of common concern to the Commonwealth and States. The Council has listed priority areas for environmental research. Working groups have been established in a number of areas, for example on Motor Vehicle Emissions, Solid Waste Management and Environmentally Hazardous Chemicals. The AEC was established in 1972 and is the most significant body in Australia for the co-ordination of environmental policy between the Commonwealth and State governments.

Council of Nature Conservation Ministers (CONCOM)

36.2.15 CONCOM comprises Commonwealth, State and Territory Ministers whose portfolios include responsibility for wildlife conservation and national parks. Its role is to advise governments on matters of national and international policy in relation to nature conservation; in particular concerning national parks and wildlife management, where common attitudes on the part of the Commonwealth, the States and the Territories are necessary to achieve an objective.

STATE GOVERNMENTS

36.2.16 Among the States there is some agreement on common environmental principles, but the way in which these are implemented and the intensity of implementation, are determined by State priorities and regional characteristics. Similarly there is considerable variation among States in administrative arrangements to deal with environmental matters. Table 36.1 summarises the bodies responsible for environmental and planning matters in the various States.

TABLE 36.1

RESPONSIBLE BODIES FOR ENVIRONMENTAL AND
PLANNING MATTERS IN THE AUSTRALIAN STATES

<u>State</u>	<u>Environmental Body</u>	<u>Planning Body</u>
New South Wales	State Pollution Control Commission	NSW Planning and Environment Commission
Victoria	Ministry for Conservation	Ministry of Planning and Melbourne Metropolitan Board of Works
Queensland	Co-ordinator-General's Department	Local Government
South Australia	Department for the Environment	State Planning Authority
Western Australia	Department of Environment and Conservation	Town Planning Department (with Town Planning Board and the Metropolitan Region Planning Authority)
Tasmania	Department of the Environment	Department of Planning and Development

36.2.17 In some States, co-ordination councils or similar bodies influence environmental objectives and research and development. Policy with respect to public involvement in environmental and planning questions varies greatly between States, the trend being towards increased public participation in most States.

36.2.18 All States have organisations responsible for the establishment, preservation and management of national parks, historic sites, nature reserves, the protection of aboriginal sacred sites and artifacts and certain species of fauna and flora. The administrative arrangements vary between States, but the powers and responsibilities are similar. Most of the State National Parks Services have some research capacity, either directly or through co-operative projects with museums, CSIRO and universities. Major emphases in these programs include the identification of land for park purposes, management-oriented research programs on individual species, wildlife population abundance and distribution, and habitat-related studies.

36.2.19 State arrangements for soil conservation are also variable. The control of noise is primarily a State responsibility in Australia and, in recent years, most States have centralised responsibility for noise control under one agency. An Interstate Noise Control Committee provides a forum for information exchange between State noise control agencies. Together with the Standards Association of Australia (SAA), the Committee provides the opportunity for standardisation of noise control requirements between States. All States have water resource, or rivers, authorities with capacity for environmental research and development as documented in Chapter 38 ('Water Resources'). Similarly, all States have departments with fishery responsibilities, whose environmental R&D is described in Chapter 21 ('Marine Sciences').

New South Wales

36.2.20 A Working Party is at present in the process of reviewing the arrangements for the co-ordinated planning of the use and conservation of land. The NSW Planning and Environment Commission advises local councils and the Minister for Planning and Environment on the adequacy of statutory planning measures, carries out research, and develops advice on the principles of town and country planning. It has strong links with other organisations including CSIRO (Division of Land Use Research), the Soil Conservation Service, and the State Pollution Control Commission (SPCC).

36.2.21 The SPCC has a number of advisory committees concerned with Clean Waters, Air Pollution etc. It administers a number of State environmental Acts; advises, supervises and co-ordinates environmental studies; and sponsors research.

36.2.22 Other bodies include the Australian Museum which has a Department of Environmental Studies, and the Metropolitan Waste Disposal Authority (MWDA) which is responsible for co-ordinating waste disposal in Sydney.

Victoria

36.2.23 The Ministry for Conservation co-ordinates a range of agencies including the Soil Conservation Authority, National Parks Service, the Fisheries and Wildlife Division, and the Environment Protection Authority (EPA). The EPA administers the Environment Protection Act (1970) which is concerned with all forms of pollution. The Land Conservation Council in the Ministry makes recommendations concerning the use of crown lands. The Environmental Studies Section has the responsibility to plan and direct regional environmental studies.

36.2.24 The Ministry of Planning contains the Town and Country Planning Board which has planning responsibility for freehold land outside the Melbourne Metropolitan Area and also co-ordinates overall State planning. The Melbourne and Metropolitan Board of Works (MMBW) has regional responsibilities which include planning for the Melbourne area, water supply and sewerage, and it commissions research in areas associated with these activities, such as catchment management.

Queensland

36.2.25 Under the Department of Local Government there is a Water Quality Council and an Air Pollution Council of Queensland with statutory responsibilities in these areas, while the Co-ordinator General's Department has environmental planning and development responsibilities.

South Australia

36.2.26 The Department for the Environment has relatively wide powers with respect to environmental matters. The Department's Director is Chairman of the State's Environmental Protection Council which can take environmental initiatives in its own right, as well as act on matters referred to it by the Minister. The Health Commission administers clean air regulations under the Health Act.

Western Australia

36.2.27 The Department of Environment and Conservation is led by a Director who is Chairman of the three-man Environmental Protection Authority, to which body Ministers have a duty to bring matters with environmental significance at the planning stage. Its powers are advisory and co-ordinating. There is also a Metropolitan Regional Planning Authority, and a Planning and Co-ordinating Authority consisting of senior Government Departmental Heads. In Western Australia the Department of Fisheries and Wildlife and the Museum both have environmental research capacity to meet their responsibilities. The Health Commission administers clean air regulations under the Health Act. Water pollution regulations are administered by individual management authorities, established under the Waterways Conservation Act.

Tasmania

36.2.28 The Department of Environment administers a number of environmental protection Acts and reviews environmental impact studies

carried out prior to major development projects. The Department of Planning and Development provides support for the State Planning Co-ordination Council (a sub-Cabinet body).

Northern Territory

36.2.29 The Commonwealth transferred State responsibilities to the Northern Territory on 1 July, 1978. It is expected that legislation will be passed by the Northern Territory Legislative Assembly later this year relating to a wide variety of environmental matters.

TERTIARY EDUCATION INSTITUTIONS

36.2.30 As a response to social concern on environmental matters, tertiary institutions have developed teaching and research in environmental areas. Universities have responded most frequently at the postgraduate level, though some undergraduate programs have been developed in both universities and colleges of advanced education. The multi-disciplinary character of research, which is typical of much environmental research, is raising policy questions for research funding in such institutions. Industry-funded research on environmental questions is also carried out by tertiary institutions.

36.2.31 Most universities in Australia have developed postgraduate training in environmental studies. In addition to degrees by research, many universities have a Masters program in environmental studies. Typically such programs have both a coursework and research component, the research leading to a dissertation or thesis. A wide range of research activities has developed in this context. Three universities have also developed training in environment and resource management at the undergraduate level, these being Murdoch University, the University of New England, and Griffith University. A significant number of colleges of advanced education has also developed courses in environmental studies or environmental science which can be the whole, or part of, the requirement for completion of an undergraduate course. Usually, environmental studies courses do not cover the social, economic, administrative and political dimensions of environmental problems. Griffith University provides the widest approach in terms of disciplines co-ordinated in the program.

INDUSTRY

36.2.32 The major companies have for some years recognised their environmental responsibilities. By R&D and the application of developed technology, they have tended to keep ahead of legal requirements. For smaller companies, the development of environmental objectives has in general followed the development and application of environmental policies by governments. Industry's main concerns are: the need for even-handed implementation of environmental policies by government agencies; greater consultation by government before new policies, standards and legislation are introduced; greater awareness by controlling agencies of the economic constraints on the rate of further environmental protection, and more consideration by government of the effects of

implementing the 'polluter pays principle'. Some evidence is emerging in Australia, as it has overseas, that environmental control requirements are generating both an 'environmental control industry' and research for developing new production technology to meet environmental criteria.

36.2.33 As well as conducting environmental R&D within individual firms, industry also funds R&D through various industry organisations, and with private consultants. Industrial organisations such as the Australian Coal Industry Research Laboratories (ACIRL), the Australian Mineral Development Laboratories (Amdel) and the Sugar Research Institute (SRI) all conduct environmental studies for the industries they represent (with varying degrees of government funding). Industry organisations including the Petroleum Institute Environment Conservation Executive, the Australian Chemical Industry Council (ACIC), the Australian Mining Industry Council (AMIC), and the Packaging Industry Environment Council (PIEC), conduct some environmental investigations themselves, as well as funding work done by other organisations.

36.2.34 A wide range of consultant firms carry out environmental studies. The studies, usually funded by either industry or government, may have a research component, but more often involve the collation and interpretation of existing information, particularly for the preparation of environmental impact statements. Although consultants lack the data-gathering and technical facilities of government, some such studies by consultants, notably in the field of environmental planning, have made a significant contribution to environmental research and development in Australia.

PRIVATE NON-PROFIT ORGANISATIONS

36.2.35 Various professional societies (such as the Institution of Engineers, Australia and the Australian Acoustical Society) as well as technical societies (such as the Clean Air Society of Australia and New Zealand and the Australian Water and Wastewater Association) provide important forums for the transfer and diffusion of environmental research and development efforts through journals, conferences and symposia. Some also play a significant role in environmental education.

36.2.36 There are also many conservation organisations in Australia. For example, bodies such as the Australian Conservation Foundation (ACF) and Friends of the Earth make inputs to public attitudes and, to some extent, to policy formulation. The ACF, a private body governed by an elected council but receiving some support from government funds, has a limited capacity for environmental studies. The ACF complements the large number of local, private, conservation bodies by concentrating its special projects on nationally important issues as well as on conservation education. Most other conservation groups have no research capacity, but there are exceptions such as the Littoral Society.

36.3 FUNDING

36.3.1 The funding of environmental R&D is complex, and figures for total expenditure, and expenditure by sector, are not readily obtained. Table 36.2 summarises available information on major R&D programs. It incorporates several estimates where information is unavailable. All figures are for a typical, recent, financial year.

TABLE 36.2

ESTIMATED ANNUAL EXPENDITURE BY
SECTOR AND AREA OF ACTIVITY (\$million)

<u>Research Category</u>	<u>Cwlth Govt(a)</u>	<u>State Govt</u>	<u>Non-govt, Industry</u>	<u>Total</u>
Environmental Pollution	6	5	4	15
Environmental Management and Conservation	14	9	0.4	23
Land Use Management and Planning	2	0.2	0.3	3
Mathematical Applications in Environmental Analysis and Management	0.4	0.5		1
<u>TOTAL</u>	22	15	5	42

(a) Includes expenditure in Commonwealth Territories as well as in CSIRO, AAEC and tertiary education institutions.

36.3.2 Based on general information obtained from the Australian Industrial Research Group (AIRG), whose members are drawn from the major companies which together carry out over 80% of the industrial R&D undertaken by commercial organisations in Australia, a summary of environmental R&D activities within AIRG is presented in Table 36.3. The discrepancies between the two tables for the industrial sector indicate the difficulties in obtaining accurate information. Industrial expenditure is thought to be understated because a considerable amount of R&D in this area is commissioned outside industry, because R&D on new technologies will often have an environmental element which is not attributed, and because of the lack of agreement on a definition of 'environmental' R&D.

TABLE 36.3

ENVIRONMENTAL R&D CARRIED OUT BY AIRG MEMBER COMPANIES

<u>AREA</u>	<u>STAFF</u>		<u>EXPENDITURE</u>
	<u>Professional</u>	Approx <u>Total</u>	1976-77 (\$m.)
Environmental Pollution			
Control	23	42	1.0
Recycling of Materials	12	26	0.88
<u>TOTAL</u>	35	68	1.88

36.4 DESCRIPTION OF R&D PROGRAMS (ENVIRONMENTAL POLLUTION AND DEGRADATION)

MARINE ENVIRONMENT

36.4.1 The increase in public interest, and of pollution agencies, has stimulated research into water quality standards, on the effect of pollutants on marine eco-systems, on models of pollutant movement, etc. States have the controlling agencies, and they support the bulk of R&D on control of marine pollution. However, only the Victorian Ministry of Conservation has developed a significant, permanent, research capability for basic problems of marine pollution. This Ministry has a Marine Studies Group with research and technical staff of around 90, devoted almost wholly to research. Research programs underway include toxicity testing by bio-assay, and the effects of urban, rural and industrial discharges on marine ecosystems. State governments have initiated research projects into areas of particular concern such as Cockburn Sound (WA), Western Port (Vic), and Botany Bay (NSW).

36.4.2 Modest research activities on marine pollution are underway in many universities and at some colleges of advanced education. Few universities have major, long-term commitments in this area. However, at the James Cook University of North Queensland, the Department of Marine Biology has a team investigating the occurrence and effects of metals in the marine environment, and the Department of Civil and Systems Engineering is investigating waste-water outfalls in shallow water, water quality simulation, tide propagation and pollutant transport in a tidal bay. Biological, chemical, and modelling activities are involved in an integrated 'Three Bays Project'.

36.4.3 The Australian Atomic Energy Commission (AAEC) has been studying the movement and dispersion of sewage from ocean outfalls by specialised tracer techniques. The work includes studies of both the waste water and the various grades of solid contaminants in the sewage. The AAEC is also studying the effect of heated effluents and of heavy metals in estuarine sediments.

36.4.4 Research on marine toxicants is being carried out at the Chemistry Department at the University of Tasmania, the CSIRO Divisions of Food Research, and Fisheries and Oceanography, the Australian Institute of Marine Science (AIMS), and the Department of Defence (Materials Research Laboratory). The CSIRO Division of Land Use Research has a small estuarine sub-program. The CSIRO Division of Fisheries and Oceanography is conducting research into methodological problems in establishing a National Marine Pollution Monitoring Network on behalf of the Joint Technical Working Group on Marine Pollution of the Australian Environment Council and the Australian Fisheries Council. This latter body is conducting a series of national workshops on analytical techniques in measuring marine pollutants.

FRESHWATER ENVIRONMENT

36.4.5 Both vegetation change by man and extensive irrigation have led to widespread increases in salinity in the southern part of the continent. In Western Australia, the problem has been related chiefly to the reduced evapo-transpiration when native vegetation is replaced by pastures, resulting in rising saline ground-waters. A joint CSIRO-State Government study is in progress. Salinity problems in the Murray River Valley have received study by the three States involved and consultants have published a major investigation of these problems for the River Murray Commission.

36.4.6 Most research on the effect of pollutants on freshwater ecology has been within tertiary institutions, particularly the University of Tasmania, Monash University, James Cook University, the Australian National University, the Caulfield Institute of Technology and the Canberra College of Advanced Education. Macquarie University (Environmental Studies Program) is investigating potential eutrophication in water-supply dams, leachates from municipal tips, and fish populations in clean and polluted rivers. Griffith University (School of Australian Environmental Studies) has programs on lake ecology and on freshwater and estuarine pollution; these include studies on hydrocarbon accumulation at different levels in the natural food chain in the Brisbane River, and the effects of pollutants associated with different land uses in an urban creek. The Centre for Resource and Environmental Studies (Australian National University) investigates river water quality using hydrological systems techniques. The University of New England is investigating water hyacinth control. James Cook University is undertaking a study, funded by the sugar industry, on the ecology of a number of North Queensland rivers.

36.4.7 The CSIRO Division of Land Use Research has a research program identifying the relationships which exist between the characteristics of a regional landscape such as cover, slope, soil morphology and the associated climatic and hydrological parameters. The CSIRO Division of Soils has been involved in soil-water studies, including hydrochemistry, for many years. Also the CSIRO Division of Land Resources Management investigates and develops predictive models for the effects of various land uses on water quality.

36.4.8 The AAEC has extensive experience in a number of areas which include isotopic tracer studies of the age and movement of groundwater, and the turbulent dispersive characteristics of natural streams (Magela Creek); studies in relation to fish populations and the effect of toxic contaminants (Finniss River and Magela Creek); the transport of radium and heavy metals in rivers (Magela Catchment); and measurement and modelling of the dynamics of surface water run-off in natural and perturbed catchments (Jabiru and Rum Jungle).

36.4.9 The Department of EHCD has completed a study of pollution abatement costs in the Australian pulp and paper industry.

36.4.10 Water quality monitoring is actively pursued by State environmental authorities. For example the State Pollution Control Commission of NSW has a computerised data bank containing results from water quality measurements in thirty rivers and estuaries in NSW, particularly those in coastal areas adjacent to Sydney, Newcastle and Wollongong as well as in some western river systems.

WATER TREATMENT (See also Chapter 38 on Water Resources)

36.4.11 Many industrial processes result in discharges of water-borne wastes. Disposal of such wastes can be a major source of water pollution if the dissolved and suspended pollutants are not efficiently removed from waste water prior to its discharge to natural water bodies. Research and technological development have been very active overseas and in Australia, significant advances have been made in the ability to deal with dissolved, or very finely dispersed, pollutants. These are particularly difficult to remove economically.

36.4.12 The successful synthesis of thermally-regenerable, ion-exchange polymers by the CSIRO Division of Chemical Technology, and its development (as the 'Sirotherm' process) by ICI Australia Ltd, provides a useful case study of the R&D sequence in improving water quality. It appears that the largest scale commercial applications of this work are likely to take place overseas in the treatment of industrial waste water to meet required quality standards. Some application to Australian industry has taken place in pre-treating boiler feed water. Such industrial applications are being introduced more quickly than those related to one of the original goals of 'Sirotherm' research - the desalting of brackish water for domestic supply.

36.4.13 The more recent development of magnetic ion-exchange resins has opened up the possibility of treating large volumes of water in simple and economical equipment, and State water authorities are involved in joint development. This world-leading research has a significance for all countries (including Australia) faced with using poorer quality water as time proceeds. The CSIRO Division of Chemical Technology is collaborating with Melbourne University and the CSIRO Division of Applied Organic Chemistry in further, related, research. The latter Division of CSIRO also maintains significant projects aimed at removing heavy metals by chelating resins (now ready for commercial development), and at removing organic constituents from water. The identification and concentration of heavy metals in sewage treatment, and the development of new, effective and biodegradable insecticides are other major projects.

36.4.14 The AAEC is investigating the treatment of waste arising from uranium mining and milling, and from the nuclear industry generally, by physico-chemical techniques such as reverse osmosis/ultra-filtration.

SOIL ENVIRONMENT

Soil pollution

36.4.15 The CSIRO Division of Soils is investigating the concentrations of potentially toxic, heavy metals in unpolluted areas and in areas surrounding Port Pirie, which receive emissions from smelter stacks, as well as the influence of soil characteristics on metal uptake and the accumulated levels in plants. The same group is also investigating the disposal of city sewage sludge, and plant uptake of heavy metals from this source. The Research Directorate of EHCD has completed a report on 'Planning for the Use of Sewage'. The possibilities and limitations of both septic tank and sewage systems are being investigated by the Soil Conservation Authority (Vic).

36.4.16 The AAEC is making an extensive study of the movement of radium and heavy metals in the soils and biota of the Magela Catchment of the Northern Territory. Other areas studied include Yeelirrie and Rum Jungle (see 36.4.8).

Salinisation

36.4.17 The extensive distribution of saline and sodic soils and the association of these with soils of high clay content, present Australia with a unique problem of terrestrial management. In particular, secondary salinisation (due to man's activities) of agriculturally significant soils is a widespread problem, due both to clearing for dry-land crops or pastures, and to irrigation. There is an intimate link between salinity and hydrology, which is recognised in the CSIRO research programs related to this problem. The distribution, properties, and identification of the problems of such soils are significant parts of two sub-programs in the CSIRO Division of Soils. The relation of increased salinity in land and domestic water supplies to the hydrologic consequences of a change in land use in Western Australia, is a major project in the CSIRO Division of Land

Resources Management, involving extensive collaboration between State, Commonwealth and industry.

Soil conservation

36.4.18 The Commonwealth and State Collaborative Soil Conservation Study is discussed under Commonwealth Government Sponsored National Programs (see 36.5.2). In addition, soil conservation research and extension is a significant activity funded by State governments in NSW, Queensland (oriented toward cultivated land), and in Victoria (chiefly on degraded pasture land). Public funds provided to all soil conservation authorities totalled \$18.6million in 1975-76, with \$15million of this being allocated from State funds. Practically all these funds (some 80%) are devoted to providing advice to the land-user and other technical services, or to land treatment (some 20%). The expenditure on R&D is of the order of 1% (ie about \$180,000).

AIR POLLUTION

Funding

36.4.19 At present, it is estimated (on the basis of manpower involvement) that some \$8.2million is spent annually on air pollution R&D. Approximately 40% of these funds is devoted to air pollution monitoring, network analysis and air chemistry, 25% to emission control and stack design, and 25% to dispersion meteorology. The balance of 10% is used in the areas of emission inventories, prediction and simulation of ambient pollutant concentrations, study of climatic implications, and research on the socio-economic implications of air pollution.

Air pollution monitoring, network analysis and air chemistry

36.4.20 The State Pollution Control Commission in NSW and the Environment Protection Authority in Victoria are active in the development of monitoring techniques and the routine monitoring and analysis of air quality data. In several States, and in the ACT, multidisciplinary air quality studies are in progress involving State and Commonwealth Government departments, the CSIRO, the Bureau of Meteorology and several groups in universities. The studies have either the management of particular sources of pollutants in mind (e.g. the Coogee and Kwinana Studies in WA and the Canberra Air Quality Study) or they are continuing programs of case studies, (e.g. studies of dispersion meteorology, or routine monitoring and network analysis). The Minerals Research Laboratories of CSIRO have a large research effort in air chemistry. Their smog chamber facility (within the Division of Process Technology) allows important basic studies of photo-chemical smog. The Laboratories are also involved in long-range studies of the rate of depletion from the atmosphere of sulphur dioxide emitted by sulphide smelters, the removal of sodium sulphate from flue gases, and the electrostatic precipitation of fly ash. An important program is also carried out at the CSIRO Division of Atmospheric Physics, where the distribution and movement of atmospheric constituents are studied at local, regional and global scales. Detailed

studies are made of nitrogen oxides, ozone, halocarbons and heavy metals in the atmosphere and extensive long-term air-sampling networks concerned with particulates have been established. The Division of Cloud Physics in CSIRO, which is concerned with those atmospheric processes which govern cloud formation and rain production, has developed a strong program of research into the origin, concentration, sizes, chemical nature and long range transport of smoke and dust particles released from natural sources as well as through man's industrial and agricultural activities. General constitutional properties of the atmosphere are being monitored at the Australian Baseline Air Pollution Station (BAPS) which is operating in a pilot stage at Cape Grim, Tasmania. It is proposed that this Station be part of the World Meteorological Organisation, Global Background Air Pollution Monitoring Network. BAPS is being developed jointly by the Commonwealth Departments of Science and EHCD in association with the Tasmanian Government. CSIRO may provide scientific guidance and carry out research under contract.

Emission control and stack design

36.4.21 Much R&D in the area of air pollution in the non-government sector in Australia is concerned with emission control, mainly from stationary sources. This includes some work on stack design, engine design and electric vehicles as well as on the adjustment of emission to meteorological conditions. Industries concerned include mining and minerals processing; the chemicals, paper, glass and sugar industries; and oil refineries. Research with electrostatic precipitators on power station stacks and copper smelters involves the Electricity Commissions of Victoria and NSW, the Minerals Research Laboratories of CSIRO, and at least two universities. Stack-design work is concentrated in the Electricity Commissions. The CSIRO Division of Process Technology is studying means of increasing the effectiveness of electrostatic precipitators and the behaviour of sulphur dioxide from smelter stacks (jointly with MIM Holdings Ltd). The AAEC has a research program into the design and performance of charcoal beds, largely based on the needs of the nuclear and radiochemical industries.

36.4.22 R&D in the area of emission control from motor vehicles involves the car manufacturers, the oil companies, and pollution control authorities in the States and Territories. No detailed information is available on R&D carried out by the car manufacturing and oil industries. However, in at least three States (NSW, Victoria and Tasmania), programs involving surveillance testing of emissions from new and in-service vehicles are either planned or are in progress. The Petroleum Institute Environment Conservation Executive is funding a study on automotive exhaust gas filtration to suppress lead and other particulate emissions. Chapter 35 ('Transport') covers some other R&D activities related to vehicle emissions and pollution control.

Air pollution dispersion meteorology

36.4.23 The Bureau of Meteorology is currently involved in a number of multidisciplinary air quality studies in Western Australia, NSW and the ACT. Groups in four universities (Melbourne, Flinders, Macquarie and Murdoch) have become actively involved in air pollution meteorology and

urban climatology. In CSIRO, the Division of Atmospheric Physics does tracer studies and experimental work on low level drainage flow, and the Division of Land Use Research is studying urban windflow patterns. Instrument development for use in dispersion meteorology is undertaken in the Department of Meteorology at the University of Melbourne and in the School of Earth Sciences at Macquarie University. Stationary and mobile, ground-based measurements, as well as remote sensing techniques, have received considerable attention. The AAEC maintains a group studying the dispersive characteristics of the lower atmosphere and is using mathematical modelling with the aim of predicting the concentration of pollutants.

NOISE POLLUTION

36.4.24 Noise is one of the most widespread environmental problems. The major research group in Australia concerned with occupational noise and its consequences is the National Acoustic Laboratory (Commonwealth Department of Health). It carries out research on the effects of noise on people and their hearing, and on hearing aids and their use. The National Health and Medical Research Council has developed model regulations for the conservation of hearing. Other Commonwealth-supported bodies whose activities include noise problems are the Australian Road Research Board, the Standards Association of Australia, and the CSIRO Divisions of Building Research and Mechanical Engineering and the National Measurement Laboratory.

36.4.25 All State governments have some noise-monitoring activity. The Noise Control Branch of the Environment Protection Authority of Victoria, has the most significant noise research capacity of the States with Western Australia and Tasmania also involved to a lesser extent in noise R&D. Some universities have noise-related, research programs (e.g. University of NSW), though these are often spasmodic. Some colleges of advanced education (e.g. the Queensland Institute of Technology) provide training in noise problems for health surveyors. There are 10 consultant firms in Australia who undertake noise studies.

36.4.26 Industry carries out, or commissions, considerable development in the design of low-noise equipment, as well as for noise suppression on existing plant and machinery.

36.5 DESCRIPTION OF R&D PROGRAMS (ENVIRONMENTAL MANAGEMENT AND CONSERVATION)

COMMONWEALTH SPONSORED NATIONAL PROGRAMS

36.5.1 Two major, national studies which were completed in 1976 and 1977 respectively were the Fraser Island Environmental Inquiry and the

Ranger Environmental Inquiry, both pursuant to the Environment Protection (Impact of Proposals) Act 1974.

Soil conservation

36.5.2 The Commonwealth and State Collaborative Soil Conservation Study (1975-77) was a broad study funded by the Department of EHCD. It involved all States, the Commonwealth and consultants. It considered soil conservation in the context of an integrated approach to land management. The terms of reference included an examination of research needs, legal, administrative, financial and equity questions of conservation implementation, and the integration of soil conservation with other areas of government policy. The Standing Committee on Soil Conservation (a committee of the Australian Agricultural Council) had responsibility for the oversight and provision of advice on the direction and scope of the study. Full reporting is expected in 1978.

36.5.3 The CSIRO Division of Soils has a program on erosion processes in landscapes. The biggest sub-program involves an investigation of the dynamics of coastal sand masses. The research objective is to understand natural erosion and deposition cycles in Australian landscapes with a view to providing management strategies for erosion control. Universities with research programs related to soil erosion and conservation, including the University of Melbourne and Griffith University, are investigating the use of absorbed atmospheric isotopes in landscape erosion studies.

The Australian National Parks and Wildlife Service (ANPWS)

36.5.4 ANPWS sponsors research in nature conservation with particular reference to implementing international agreements (e.g. the Japan-Australia Migratory Birds Agreement, and the Endangered Species Convention) and administers the Natural Environmental Investigations and Surveys program (NEIS) which, in co-operation with the States, examines conservation and management of Australia's flora and fauna and their habitats.

Australian Biological Resources Study (ABRS)

36.5.5 The ABRS is a program established within the Department of Science; it provides funds for studies aimed at developing an inventory of Australian flora and fauna and, in co-operation with the States, it is developing a data retrieval system for taxonomic and distributional information. It has funded 88 projects since 1974, largely in museums, herbaria, universities and other tertiary institutions.

CSIRO ecological research

36.5.6 The CSIRO Division of Wildlife Research carries out research aimed at management and conservation of Australia's flora and fauna. The general objectives of the Division's research are to study the status and basic biology of species of birds and mammals (both native and introduced) and the interaction of the species with their environments, and to show how this knowledge might be applied in the management of wildlife populations.

36.5.7 The major research objective of the Woodland Ecology program of the CSIRO Division of Land Use Research is to understand the effect, in particular woodlands and forests, of disturbance and man's use on the Australian vegetation and its stability. The CSIRO Division of Forest Research has long-term studies concerning management of Australian forests. The CSIRO Division of Land Resources Management is developing ecologically-based, management methods to improve and maintain forests. The Division is investigating the consequences of operations such as burning and clearing of forests and is responding to the problem posed by the rapid spread of the soil-borne disease *Phytophthora cinnamomi* by studying its ecology and possible methods of control.

Ecological surveys

36.5.8 The CSIRO Division of Plant Industry has a long-term project concerned with the ecological survey and classification of rainforest communities in Australia, and with factors affecting the distribution and conservation of natural grasslands and coastal heaths. The feasibility of undertaking an ecological survey of Australia utilising LANDSAT data has been explored in South Australia in a project jointly funded by the Department of EHCD, the South Australian Department for the Environment, and the CSIRO. The Zoology and Botany Departments of most universities and other academic groupings with ecological research capacity (e.g. the School of Australian Environmental Studies at Griffith University, and the (largely postgraduate) environmental studies activities of other Australian universities) have also carried out a very wide range of research, usually of a fundamental kind, which is drawn upon by National Parks and Wildlife Services, or equivalent bodies, in the States to complement their own research.

Land use management and planning

36.5.9 Two major programs of the CSIRO Division of Land Resources Management concern the management of agricultural lands and the management of Australia's vast range-lands. Research includes assessment of land condition, and the development of realistic, low-input, management practices to improve land condition. The Division is also evaluating the utility of LANDSAT data for broad-scale survey applications, including surveys of wetlands, *Phytophthora* damage, bathymetry, soil salinisation, and range condition. The same Division is providing information and developing a methodology for resource managers and planners in situations where incompatibilities between alternative resource developments lead to conflicts of interest. The CSIRO Division of Land Use Research has a range of projects on resource inventory and evaluation, survey methodology, land evaluation and the development of planning methods for land allocation. The Division has collected a vast information base on biophysical resources through its extensive surveys, and is developing methods of computer storage, use, and display of such geographically-based data in the planning of land use. A major project on the south coast of NSW, recently completed by the CSIRO Division of Land Use Research, has resulted in a comprehensive methodology for planning land use. Geographically-presented, inventory information was used to develop a 'preferred' pattern of land use in terms of satisfying the constraints imposed by the land's varying capacity and suitability.

Tertiary institutions with research related to land use planning include the University of Melbourne, Monash, Murdoch and Griffith Universities, the University of Tasmania, and the Canberra College of Advanced Education. The University of Melbourne's Centre of Environmental Studies lays particular research emphasis on landscape and environmental planning.

COMMONWEALTH SPONSORED REGIONAL PROGRAMS

36.5.10 The Alligator Rivers Region Environmental Fact Finding Study was jointly funded by the Commonwealth Government and the interested mining industry to provide a framework of general environmental information concerning the region. The study was undertaken by the AAEC, several divisions of CSIRO and the Department of the Northern Territory together with some private consultants; it was completed in December 1973.

36.5.11 The Gascoyne Region Desertification Study considered the consequences of long-term over-grazing of rangelands by sheep. It was jointly funded by CSIRO, the Western Australian Government and the Department of EHCD, and the results were presented at the UN Conference on Desertification in 1977.

36.5.12 Other regional studies include the Gold Coast Region Sewage Disposal Study (completed in September 1976) which was commissioned by the Queensland Government, and the Parramatta River Region Basin Drainage Study which was also completed in September 1976 and which looked at alternatives to conventional stormwater drainage.

STATE PROGRAMS

New South Wales

36.5.13 The Botany Bay Environmental Control Study is managed by the NSW State Pollution Control Commission (SPCC). One of the main aims of this study is to develop a comprehensive, water-resources management plan for Botany Bay and its tributaries. Scheduled for completion in 1978, this major co-operative study involves the Maritime Services Board, the NSW Planning and Environment Commission, the Universities of Sydney and NSW, and the NSW Lands Department. The study is concerned with the capacity of water-related resources to meet present and future uses. It considers the effects of pollution and of activities on the resources, and examines the options and practicability of alternative means of water resource protection.

36.5.14 The Namoi Valley Environmental Study is co-ordinated by the SPCC, with sub-programs executed by various government agencies and the University of New England. This study investigates the possible, unintended consequences of using chemical insecticides to control pest species in agriculture (especially on cotton crops), reviews alternative pest-control practices, and provides a basis for environmental control programs.

Victoria

36.5.15 The typical objectives of a series of Victorian studies are to appraise regional resources and provide a basis for their management. The Port Phillip Regional Study, which was commenced in 1967 as a Phase I investigation on treated sewage disposal in the Bay, (and reported in 1973), was expanded subsequently to the current Phase II which includes the establishment of management guidelines for waste disposal into the Bay. The State's protection policy for the Bay is based on this study.

36.5.16 Phase I of the Westernport Bay Environmental Study (1973-74) followed proposals for a major deep-water port and large-scale industrial development in Western Port. Interested industry contributed part of the cost of Phase I of the study, which developed new methodology for such studies, with reports concentrating on evaluating possible environmental consequences of, and management requirements for, proposed developments, based on systems understanding. Phase II, now half complete, is providing information to planning, monitoring and management bodies with responsibility for the region.

36.5.17 The Gippsland Regional Environmental Study, which commenced recently, has as its main objective the prediction of environmental effects of further development of the total resources of the Gippsland Lakes catchment. The study provides management advice for the responsible authorities and will produce a final report in 1981.

Queensland

36.5.18 The South Queensland Coastal Management Study is a consultant study commissioned by the Co-ordinator-General's Department. It provides an overall resource evaluation and management plan for the coastal strip of south eastern Queensland. It pays particular attention to land use management, including wetland and aquatic areas, and provides an engineering evaluation of canal estate development. A number of other studies of coastal, island, or catchment management have also been carried out, or more commonly, commissioned to engineering consultants.

South Australia

36.5.19 The Spencer Gulf Study, commenced in 1973, is an inter-governmental and inter-institutional study of the water resources of the Gulf as affected by actual and proposed industrial and urban activity. It is co-ordinated and sponsored by the Department for the Environment.

36.5.20 A number of regional studies have also been organised, such as those dealing with the clearance of native vegetation and with the management of the Flinders Ranges area.

Western Australia

36.5.21 The Cockburn Sound Environmental Study was commenced in early 1977 with the aim of better understanding the environment of the Sound, which is fringed by a wide range of industry.

36.5.22 Studies of the estuaries of the south-west of Western Australia were commenced in 1974. They include the Blackwood Estuary Study (examining the likely consequences of a dredging proposal), and the Peel-Harvey Estuarine Systems Study (concerned with eutrophication studies in a popular tourist area).

Tasmania

36.5.23 The Department of the Environment has a major concern with the effect of heavy metals in the environment and, jointly with other agencies and with the University of Tasmania, has initiated a number of studies under this theme. These include Lead in Air from Motor Vehicles (commenced in 1976) and a number of studies of heavy metals in the marine environment, particularly on the north west coast of Tasmania, and in the River Derwent, where heavy metals in oysters are of concern to human health. Studies of problems associated with effluent disposal from particular industries (e.g. a paper mill on the Derwent River), with sewage disposal, and with noise control, have also been undertaken.

Australian Capital Territory

36.5.24 The Canberra Air Quality Study, sponsored by the National Capital Development Commission (NCDC) and involving CSIRO, the Australian National University and the Canberra College of Advanced Education, is aimed at providing a basis for planning to meet ambient air quality goals with air pollution due chiefly to vehicular emission.

36.5.25 The ACT Regional Basin Water Quality Study was sponsored by the National Capital Development Commission and involved Commonwealth Departments and institutions within the ACT. The study aimed to establish water quality objectives for the Upper Murrumbidgee River basin, and to evaluate control methods. The NCDC and the Department of the Capital Territory are developing studies using interactive computing to aid the use of information on terrain, and from ecological and geological surveys in planning new towns.

MATHEMATICAL MODELLING

36.5.26 Applicable mathematical methods, including computer simulation, are commonly used to express quantitatively, hypotheses concerning the most significant features of environmental systems. Mathematical models are used in most regional programs of air quality control models such as at Kwinana (WA) and models of water quality in Western Port (Vic). The techniques of mathematical modelling are typically used in close association with an experimental program, and aid the development of a conceptual understanding of systems. The CSIRO Division of Computing Research is a main centre of research in Australia into simulation methodology. Simulation studies, including the development of methodologies, are conducted by a number of CSIRO Divisions. There is a wide range of mathematical research in tertiary education institutions of relevance to the analysis and representation of environmental systems. Teaching and research in mathematical modelling as applied to environmental problems is carried out in the School of Australian Environmental Studies, Griffith University.

APPENDIX 36.1

MINING RECLAMATION

Mine reclamation R&D in Australia is largely tactical, aimed at overcoming clearly discernible problems. In total there are approximately 20 ecologists involved. Usually each mine site is considered in isolation by the company or government organisation concerned. Apart from the work of the AAEC at Rum Jungle, little basic or strategic R&D is carried out. Legal requirements for reclamation vary from State to State, and are not always enforced uniformly. Mining companies differ in their attitude to reclamation work, and claim that they often receive conflicting advice.

Mine reclamation is carried out in a very wide range of environments in Australia, from the tropical north to Tasmania, and from areas of very high rainfall to semi-arid regions. Each site may have its own particular problems, but the main requirements are common to most sites. These are:

- . containment of tailings and other wastes (sometimes toxic);
- . landscaping of dumps, quarries and open cuts;
- . stabilisation of soil, fill, overburden dumps and waste;
- . removal or neutralisation of toxic components;
- . establishment of vegetation; and
- . safety measures including fencing;

Some research results obtained from one mining site may be directly applicable at another site; for example, information on the construction of tailings dams or on the prevention of heavy metal toxicity. The Australian Mining Industry Research Association (AMIRA) conducts workshops for mining industry environmental officers to exchange information and research results, particularly on revegetation and rehabilitation of sites.

There are several examples of successful reclamation work carried out in Australia. In beach-sand mining the process of extraction is entirely mechanical and only a small volume of material is removed, making reclamation relatively simple once the mined area has been landscaped. In some cases the topsoil, containing seeds of the natural vegetation, has been carefully removed, stored and then replaced after the completion of mining; this has provided a sound basis for the revegetation of mined areas with natural plant species. Very large sums have been spent on revegetation, the aims being, first, to establish a ground cover to prevent wind erosion, and then to introduce long-lived, native woody species in an attempt to recreate something as close as possible to the natural vegetation.

The bauxite mining industry has also given emphasis to revegetation with native plant species in both Western Australia and the Northern Territory in the hope that such communities will not require continuous maintenance in the form of supplementary water, fertiliser or mowing, as is the case when agricultural pasture species are used. There have been problems with these projects; in particular some of the species utilised have proved to be fast-growing, but unsuitable in the long term.

In South Australia the quarry industries pay a levy, on each tonne of material extracted, into a State-administered Reclamation Grants Board. Each company is then able to apply for grants from the Board to support approved schemes, and projects are regularly inspected before further funds are granted. This ensures that areas are landscaped and revegetated to acceptable standards, a practice further encouraged when companies actually own the land and are able to resell it at a profit.

CHAPTER 37

ATMOSPHERIC SCIENCES



Photograph: Two observers from the Bureau of Meteorology station at Laverton, Victoria, preparing to launch a hydrogen-filled balloon carrying a radar reflector (the target is on the ground) and a radio-sonde (held by the observer in the foreground). The characteristics of winds above Laverton will be derived by tracking the balloon with the WS 44 radar on the roof of the office, and temperature and humidity profiles will be obtained from signals transmitted from the radio-sonde. Thousands of similar launches take place around the world each day.

(Photograph courtesy Bureau of Meteorology).

CHAPTER 37

ATMOSPHERIC SCIENCES

37.1 BACKGROUND

DEFINITION OF AREA COVERED

37.1.1 For the purposes of this report the atmospheric sciences are regarded as encompassing both conventional meteorology and the physics and chemistry of the earth's upper atmosphere. Although sometimes used restrictively to refer only to phenomena that relate directly to weather and climate, meteorology is a term which covers that portion of the atmospheric sciences concerned with the physics and chemistry of the earth's atmosphere as a continuum. This includes problems of the troposphere, the stratosphere and the mesosphere, and studies of such phenomena as the general circulation, weather systems, precipitation processes, turbulence, diffusion and atmosphere-surface interactions. Areas of meteorological interest extend from the surface to approximately 100km. The upper atmosphere sciences cover problems of the mesosphere and thermosphere including the ionosphere, and studies of such phenomena as airglow, aurorae, magnetic fields, radiation belts and solar-terrestrial relationships. The domain of primary interest to the upper atmosphere sciences extends from approximately 50km above the earth's surface to outer space.

37.1.2 In view of the greater diversity of establishments and programs concerned with problems of the lower atmosphere, the pattern of meteorological research in Australia is treated in more detail in this Chapter than are the arrangements for upper atmosphere research.

37.1.3 Meteorology may be subdivided by primary scientific discipline (physics, dynamics, chemistry), by scale of phenomenon, by region, by method of study, by field of application, and in other ways.

37.1.4 A distinction is sometimes drawn between 'meteorology' and 'climatology', the latter being concerned primarily with the average rather than the instantaneous state of the atmosphere, but climatology is here regarded as an integral part of the science of meteorology. There is also substantial overlap between meteorology and related sciences such as hydrology and physical oceanography, and strong interaction with many fields of applied research such as land and water resources management, air pollution, and solar energy research. These fields of study are described in other chapters of this Report.

37.1.5 For the purposes of later classification and program description, only the following broad categories are adopted. They follow closely those

used by the Interdepartmental Committee for the Atmospheric Sciences of the US Federal Council for Science and Technology.

(a) Physical meteorology:

the study of the optical, electrical, acoustic and thermodynamic phenomena of the atmosphere; the laws of radiation, and the explanation of clouds and precipitation. Boundary layer meteorology, air-sea interaction, and atmospheric turbulence are sometimes included as part of physical meteorology.

(b) Dynamic meteorology:

the study of atmospheric motions as solutions of the equations of hydrodynamics or other systems, or equations appropriate to special situations, as in the statistical theory of turbulence. Studies of geophysical fluid dynamics, though broader in scope, may be grouped with dynamic meteorology.

(c) Atmospheric chemistry:

the study of the reactions and changes of phase of elements and compounds that take place within the atmosphere, and the distribution, sources, transport, and sinks of these substances.

(d) Observational meteorology:

the functions of sensing, measuring or otherwise determining the state of the atmosphere and the magnitude of its phenomena.

(e) Synoptic meteorology:

the description and study of weather systems as depicted on conventional weather maps and charts.

(f) Climatology:

the scientific study of climate, including the description of climate, the analysis of its causes (physical climatology) and its application to specific problems (applied climatology).

(g) Prediction:

the forecasting of atmospheric variables and phenomena whether done by manual or automated methods.

(h) Applied meteorology:

the application of meteorological data and understanding to specific problem areas, e.g., air pollution, aviation, shipping, agriculture and water supply, and the urban environment.

(i) Oceans and ice:

oceanography and glaciology are themselves major fields of science. The concern here is with interactions between the atmosphere and the underlying oceans and polar ice.

POLICIES AND AGREEMENTS

37.1.6 The present pattern of organisation and conduct of atmospheric research in Australia owes much to both historical and geographical factors. In particular it has been influenced by the evolution, since Federation, of the Bureau of Meteorology as the organisation responsible for provision of national meteorological services. Under Section 51(viii) of the Constitution, the Commonwealth Government has the power to make laws with respect to astronomical and meteorological observations. The Meteorology Act of 1955 specifically charged the Commonwealth Bureau of Meteorology with the promotion of the advancement of meteorological science, by means of meteorological research and investigation or otherwise (Meteorology Act 1955, Section 6(g)). In a subsequent clarification of the Act, the Cabinet, in April 1957, decided that the Director of Meteorology should be given the necessary facilities to establish a hydrometeorological service to carry out, inter alia, research and investigation necessary for the application of meteorology to hydrological problems.

37.1.7 In 1937, on the basis of a report on the need for a source of university training and research in meteorology, a Meteorology Department was established at the University of Melbourne. Initially, all the funds for running the Department were provided directly by the Commonwealth and much of its research was inspired by the operational requirements of the Bureau. The Bureau continued to provide a part of the Department's running costs until 1976.

37.1.8 In 1946 the Commonwealth Scientific and Industrial Research Organisation (CSIRO) created what is now the Division of Atmospheric Physics (DAP). The decision to establish a new meteorological research organisation was taken after discussion with the Bureau: it was agreed that the existence of the Division and its studies of particular problems in meteorological physics should not be interpreted as any indication that CSIRO should, or indeed could, fulfil the research role of the Bureau. The CSIRO Divisions of Cloud Physics (DCP) and Environmental Mechanics also have research programs in the atmospheric sciences. The DCP was formed in July 1972 from the former Cloud Physics Section of the Division of Radiophysics. Work on cloud physics in this section had begun as early as 1947, when cloud seeding experiments were initiated by the Radar Meteorological Research Group in the Division of Radiophysics. The Division of Environmental Mechanics was formed in 1971 with most of the foundation staff coming from the Agricultural Physics Section of the Division of Plant Industry. The Section had been established at Deniliquin in 1955 and moved to Canberra in 1958, occupying the Pye Laboratory in 1968.

37.1.9 Between 1965 and 1969, extensive discussions took place at the official, Ministerial and Cabinet levels on proposals for a strengthened research program in the Bureau of Meteorology. In 1967 three major reports were prepared. They were: 'Prospectus for meteorological research in Australia', by W.J. Gibbs, C.H.B. Priestley, and F.W.G. White (1967); 'Report on a proposed meteorological research programme', by G.B. Tucker and P.V. Moran (1967); and 'Some problems of research and education in Australian meteorology-Report of consultant to the World Meteorological Organization' by H. Riehl (1967). Finally, in 1969, the Commonwealth Meteorology Research Centre was established under the terms of an agreement between the Bureau, CSIRO, and the Public Service Board. The Centre was re-named as the Australian Numerical Meteorology Research Centre (ANMRC) in 1974 under the terms of a new agreement between CSIRO and the Department of Science.

37.1.10 At the international level, Australian involvement in atmospheric research is, to a large extent, associated with membership of the World Meteorological Organization (WMO), an agency of the United Nations. The WMO Convention (1947), to which Australia is a signatory, identifies as among the purposes of WMO, 'to encourage research ... in meteorology and, as appropriate, in related fields and to assist in co-ordinating the international aspects of such research ... and to further the application of meteorology to aviation, shipping, water problems, agriculture and other human activities.' In 1965 the Government agreed that, along with the USA and the USSR, Australia would operate a World Meteorological Centre of the WMO World Weather Watch, a global system of exchange of meteorological information for operations and research. Apart from the World Weather Watch, the main impact of WMO on Australian atmospheric research occurs through the programs and activities fostered by its Commission for Atmospheric Sciences (CAS) and through the Global Atmospheric Research Program (GARP), a co-operative international venture sponsored jointly by the WMO and the non-governmental International Council of Scientific Unions (ICSU). As a national reflection of arrangements under the international agreement between WMO and ICSU, an Australian National Committee for GARP, appointed jointly by the Australian Academy of Science and the Director of Meteorology, has responsibility for fostering Australian participation in the Program.

37.1.11 Other influences on Australian atmospheric research, through national adherence to ICSU, occur via the various programs of the International Union of Geodesy and Geophysics (IUGG) and particularly its International Associations of Meteorology and Atmospheric Physics (IAMAP), Geomagnetism and Aeronomy (IAGA) and Physical Sciences of the Ocean (IAPSO) and their various Commissions. Recently, there has been increasing involvement with the Scientific Committee on Problems of the Environment (SCOPE).

37.1.12 No recent, definitive statement of national policy objectives for Australian atmospheric research exists. The decisions and initiatives by governments over the past 30 years have shaped the thrust of objectives. These may be summarised as:

- . Australia should make a special contribution to knowledge of the southern hemisphere atmosphere (by analogy with statements of policy on research into the southern sky and southern ocean; the Government decision of 1965 that Australia would operate the first World Meteorological Centre in the Southern Hemisphere);
- . the operations of the Bureau of Meteorology should be supported by research (Ratification of the WMO Convention in 1947; Meteorology Act 1955; Cabinet Decision of 1957 establishing a hydrometeorological service in the Bureau; Cabinet decision of 1969 to establish the Commonwealth Meteorology Research Centre);
- . a national atmospheric research program should include a component in the universities (Government decision of 1937 to set up and support atmospheric research in the University of Melbourne);
- . the national atmospheric research program should not be restricted to the mission-oriented agencies and the universities but should involve also a strong component in CSIRO (decision of 1946 to set up the Meteorological Physics Section of CSIR and subsequent developments in the organisation of atmospheric research in CSIRO);
- . Australia should support global atmospheric research and monitoring programs such as the Global Atmosphere Research Program (GARP) and the Global Environmental Monitoring Systems (GEMS);
- . Australia should play a special role in Antarctic meteorology (claims to Australian Antarctic Territory and recent emphasis on Antarctic resources and management: Director of Meteorology's responsibilities for meteorology in Australian territories);
- . the Bureau's activities should relate to national objectives, and revenue should be raised from its services (terms of reference for the Committee of Inquiry into the Bureau of Meteorology, 1976);
- . the use of meteorological information should be promoted in Australia (Meteorology Act, Section 6(f)).

37.1.13 Only the Bureau and CSIRO Divisions have carried out programs that are substantial enough to have been related to national objectives. The decisions of the Commonwealth Government to mount a special Southern Ocean drifting buoy program in support of the First GARP Global Experiment and to set up a Baseline Air Pollution Station in Tasmania can be seen as specific but very limited realisations of the fifth objective above.

ORGANISATION

37.1.14 By far the largest R&D effort in the atmospheric sciences is in the Commonwealth sector. Three institutions dominate: the CSIRO (mainly the Divisions of Atmospheric Physics and Cloud Physics), the Bureau of Meteorology (primarily a service organisation but with a headquarters R&D Branch and significant R&D effort also in its other headquarters branches and its Regional Offices), and the jointly operated ANMRC. Several other CSIRO Divisions include meteorological components within their programs, and some Commonwealth Government departments have responsibilities which involve the funding or mounting of a limited amount of lower and upper atmospheric research.

37.1.15 In the tertiary education sector, 16 of Australia's 19 universities, and about 10 colleges, have research programs of varying size. There are small, isolated mission-oriented programs in the State government sector. Research in the private sector is limited mainly to three or four groups, engaged in work related to environmental impact statements, building, bridge and harbour design and the like. A few large business enterprises have employed meteorologists in specific support roles involving some R&D effort.

37.1.16 Interaction and co-operation between the various organisations involved in atmospheric research in Australia are relatively informal and tend to have developed mainly from individual scientist-to-scientist liaison and through such mechanisms as joint meteorological colloquia and, more recently, the activities of the Australian Branch of the Royal Meteorological Society. Most research groups find themselves dealing with the Bureau of Meteorology from time to time, if only for purposes of obtaining meteorological data from the Bureau's national data bank. CSIRO and the Bureau have been involved in a significant number of collaborative research programs (including loan of equipment) with various universities, and with each other. National co-ordination in particular areas is effected through such bodies as the National Committee for GARP and the Water Research and Education Committee of the Australian Water Resources Council. In areas such as tropical meteorology, numerical weather prediction, weather modification and agro-meteorology, annual or quadrennial reports to the World Meteorological Organisations serve as a useful focus for information exchange and for identification of the elements of a national program. Within Australia, information on research activities is published in the annual reports of the Bureau, of the CSIRO Divisions and of the ANMRC, and can be obtained through the CSIRO Central Information, Library and Editorial Section.

37.1.17 An estimate of the funds directed to atmospheric research in Australia in 1977 is given in Table 37.1, which shows the distribution by major sectors of performance and by program.

TABLE 37.1

ESTIMATED EXPENDITURE ON ATMOSPHERIC RESEARCH
IN AUSTRALIA; 1977 (\$'000)

PROGRAM	Dept of Science	C S I R O				Other Cwlth Govt	Tertiary Education Sector	State Govt	Business Enterprise and Private	TOTAL
	Bureau of Met	ANMRC	Atmos Physics	Cloud Physics	Other CSIRO					
Physical Meteorology	175	20	500	630	235	40	100	10		1710
Dynamical Meteorology	35	130	300	50			100		5	620
Atmospheric Chemistry	0	20	500	200	255	10	20	30	10	1045
Observational Meteorology	280	90	100	50	70	30	120	30	10	780
Synoptic Meteorology	280	90	100		10	20	160	5	15	680
Climate	70	285	250		110	75	340	35	55	1220
Prediction	175	300					40		60	575
Applied Meteorology	350		150	50	190	90	320	105	60	1315
Oceans and Ice	35	45	75		150	95	100	10	15	525
Upper Atmosphere	0	20	25	20	100	1000	1100			2265
TOTAL	1400	1000	2000	1000	1120	1360	2400	225	230	10735

37.1.18 The R&D effort of the Bureau of Meteorology is distributed widely through the Bureau and the estimate of research expenditure in Table 37.1 is aggregated from the appropriate portion of the salary and other costs associated with the small R&D component of the work of many officers. It includes an allowance for computing, administrative support, equipment, travel and other costs directly attributable to R&D but excludes all costs associated with the purchase of new capital equipment (except equipment for research purposes) and the routine data-gathering and data-processing operations of the Bureau. All but a few tens of thousands of dollars of the Bureau's R&D funds derive directly from Commonwealth appropriation. Expenditure on R&D accounts for slightly less than 4% of the annual operating cost of the Bureau.

37.1.19 The funds listed in Table 37.1 for the CSIRO Divisions of Atmospheric Physics and Cloud Physics, and the ANMRC, correspond approximately to the total annual operating costs of the respective organisations. The estimates of expenditure on atmospheric R&D in other CSIRO Divisions are based on estimates of the full-time-equivalent research manpower and an allowance of \$50,000 as the annual cost for each full-time-equivalent scientist so engaged. Although a small part of the CSIRO expenditure on atmospheric research derives from consultancy and contributory funds, by far the largest part is from Commonwealth appropriation.

37.1.20 Estimates of R&D expenditure elsewhere in the Commonwealth and State Government sectors are based on estimates of full-time-equivalent professional manpower involved in research, and an allowance of \$40,000 per full-time-equivalent researcher per year. In the private sector the corresponding figure used was \$35,000.

37.1.21 Firm estimates for expenditure on atmospheric R&D in the tertiary education sector are not easily determined. A large part of the expenditure derives from the appropriate portion (varying from about 5% to about 50%) of the academic salaries of university and college staff. To this must be added the bulk of the salary/allowances of full-time higher-degree students, some part of the technical and other support staff, some overheads such as computing costs and most of the grants from sources such as the Australian Research Grants Committee (ARGC), the Water Research Fund, Radio Research Board and similar sources. Total ARGC funding for the areas identified as 'meteorology' and 'upper atmosphere sciences' in this chapter is estimated at \$100,000 and \$400,000 respectively. On the assumption that each academic staff member spends about one-third of his efforts on research, the formula adopted here allowed \$20,000 out of the estimated \$60,000 expenditure associated with each staff member. Adjustment was made where the involvement with atmospheric research was substantially less than 30% or where the ratio of research students to staff was particularly high.

37.1.22 Some care is needed in interpreting Table 37.1 and, in particular, in drawing comparisons between the various sectors of performance. This arises because of the very different patterns of operation of the primarily research-oriented organisations on the one hand,

and the primarily teaching or service-oriented organisations on the other. Moreover, the boundary between research and teaching operations has been determined arbitrarily and, for the tertiary education sector, expenditure has been estimated from salaries, although student participation provided a large component of the manpower.

37.2 DESCRIPTION OF R&D ESTABLISHMENTS

COMMONWEALTH GOVERNMENT

The Bureau of Meteorology

37.2.1 The research program of the Bureau supports its service functions in meteorology and hydrology, and the advancement of meteorological science. It is concentrated in a Head Office Research and Development Branch, but a significant component of R&D work is also undertaken in the Bureau's other Head Office branches and in its Regional and Field Offices. The Research and Development Branch has responsibilities in addition to research, the research component of its program accounting for about half of its 26 professional and 20 support staff.

37.2.2 The main areas of research (and full-time equivalent professional manpower) during 1977 were: hydrometeorology (6) including rainfall climatology for flood estimation and development of flood forecasting; synoptic meteorology (2) including methods of analysis and prognosis, objective specification of weather elements, circulation studies and synoptic and dynamic climatology; physical meteorology (6) including boundary layer processes, analysis and prediction of the state of the sea, satellite-based cloud studies, and the use of radar in tropical cyclone forecasting and estimation of areal rainfall; general applied meteorology (2) including climatic change and variability, air pollution and micrometeorology; and a series of small studies in miscellaneous fields of application.

37.2.3 Other programs are located in the Bureau's Head Office, Services (4), Facilities (6), and ADP (4) Branches and there is an aggregate research effort equivalent to about 10 scientists full time in the Regional Offices. The Bureau co-ordinates research related to programs of the World Meteorological Organisation (WMO) and its Commissions.

CSIRO Division of Atmospheric Physics (DAP)

37.2.4 The Division is concerned with the physical and chemical atmospheric processes that underlie and control the weather, the climate, and the distribution of airborne gases and other material affecting the quality of the environment. It undertakes field experiments and

observations, laboratory experiments, and analytical and numerical modelling. The staff of 88 comprises 25 research scientists, 16 experimental support staff and 47 technical and clerical staff. The six main research programs are: radiation - solar and thermal (6), including the influence of radiation on predictability and climate, the interaction of radiation and clouds, and the establishment of parameters for radiation in climate models; dynamic climatology (8), including the physical basis of climate on seasonal and year-to-year time scales; atmospheric chemistry (10), including the distribution, sources, sinks, transport and long-term trends of atmospheric constituents likely to affect climate; geophysical fluid dynamics (6), including theoretical analysis and laboratory studies relating to motions in the atmosphere and oceans; regional meteorology (5) including near-surface micro- and meso-scale meteorology with particular reference to pollutant dispersal in the Latrobe Valley; and air-surface interaction (5), including exchange processes between the atmosphere, and sea or land. The Division is responsible for maintaining the standards of an Australia-wide network of observations of stratospheric ozone, and for national standards and calibration services in radiation and anemometry. It co-operates with many other Australian groups. Several of the staff are members of Commissions of the International Association of Meteorology and Atmospheric Physics (IAMAP), and also serve on a number of WMO and GARP bodies.

CSIRO Division of Cloud Physics (DCP)

37.2.5 The objectives of the Division are the study of cloud behaviour and its possible modification (in particular to increase precipitation), and the impact of man's everyday activities on weather and climate. The DCP maintains an instrumented aircraft for field observations, with complementary laboratory and theoretical programs. The staff of 45 comprises 12 research scientists, 8 other professionals, and 25 technical and clerical support staff. Further technical support and services are provided by the CSIRO Division of Radiophysics which shares the laboratory site.

37.2.6 The two main research programs of the Division are: cloud physics and precipitation (14), including field, laboratory and theoretical studies of microphysical and dynamic processes on natural and artificially stimulated rain; and atmospheric aerosols (6), including collection and study of man-made and natural tropospheric and stratospheric particulates and their effects on weather and climate, and studies of the dispersal of particles from known pollution sources. The Division has a high international standing, particularly for its field measurement program and for its techniques of assessing the suitability of areas for cloud seeding experiments. Co-operative programs are carried out with other institutions in Australia and abroad, and the DCP plays an active role in international programs such as the planning phase of the WMO Precipitation Enhancement Projects

Australian Numerical Meteorology Research Centre

37.2.7 The objectives of the Centre include the study of the general circulation and climate and the improvement of weather forecasting, using numerical models. The staff of 34 comprises 10 research scientists and 2 administrative staff provided by CSIRO, and 10 meteorologists, 3 programmers, and 8 technical and typing staff provided by the Bureau. The ANMRC has developed many of the Bureau's numerical analysis and prognosis systems. Several its models have been adopted abroad.

37.2.8 The three major research programs of the Centre are: diagnostic studies (4), including investigations based on observations of the atmosphere, and studies of the budgets of mass, energy and angular momentum of numerically-produced models of synoptic-scale weather systems; general circulation studies (7.5), including work on model development, extended integrations of spectral and semi-spectral models, and a number of geophysical experiments; and weather research (11.5), including initial state specification using satellite and other data, hemispheric forecasting experiments, and development of a limited-area forecasting model.

Other CSIRO Divisions

37.2.9 Approximately 12 other CSIRO Divisions operate smaller programs of atmospheric research. These include: the Division of Environmental Mechanics with a program in micrometeorology (3), including boundary layer studies of heat, momentum and water-vapour transfer above and within plant canopies, flow past surface heterogeneities and flow near bluff obstacles and shelter belts; the Division of Process Technology with a program in air pollution (5), including sulphur dioxide emissions, the formation of photochemical smog and the brown haze often seen over Sydney, the kinetics of reactions involving free radicals, and the production of chlorocarbons from salt; and the Division of Land Use Research with a program in urban meteorology and regional climate (2), especially for the Canberra region. Other Divisions with some involvement include the Division of Fisheries and Oceanography (drifting buoy development, ocean circulation studies), the Division of Land Resources Management (wind climatology and air pollution), and the Divisions of Soils, Building Research, Radiophysics, Mathematics and Statistics, Entomology, Forest Research, and the Solar Energy Studies Unit.

Other Commonwealth agencies

37.2.10 In the Commonwealth sector, the main atmospheric research effort outside the Bureau of Meteorology and CSIRO is directed to upper atmosphere research with significant programs, each involving several scientists, in the Defence Research Centre, Salisbury, of the Department of Defence, and in both the Antarctic Division and the Ionospheric Prediction Service of the Department of Science. Both theoretical (including modelling) and observational studies are involved, with particular projects directed to such aspects as atmospheric composition, structure and variability of ionospheric winds, the relationships between

phenomena of the upper atmosphere that are due to the solar wind (for example, auroral and magnetic disturbances), and phenomena of the lower atmosphere related to weather and climate.

37.2.11 Lower atmosphere research is limited to isolated small programs involving, at most, one or two scientists in such organisations as the Australian Atomic Energy Commission (mainly boundary layer studies), Telecom Research Laboratories (radiometeorology), the Department of Environment Housing and Community Development (regional and urban climatology), Royal Australian Navy Research Laboratories (air-sea interaction), Aeronautical Research Laboratories (turbulence and thunderstorm gust structures) and the Snowy Mountains Engineering Corporation (hydrometeorology).

TERTIARY EDUCATION INSTITUTIONS

Physics Department, La Trobe University

37.2.12 The Department maintains a very active program of upper atmosphere research involving five academic staff, technical support and a number of postgraduate students. The research includes work on ionospheric irregularities, aurorae, airglow, magnetic pulsations, microbaric activity and magnetospheric studies. Members of staff are heavily involved in national and international programs such as the Middle Atmosphere Program (MAP) conducted by the Special Committee on Solar Terrestrial Physics of the International Council of Scientific Unions.

Meteorology Department, University of Melbourne

37.2.13 The staff of 14 comprises 4 academic staff, 3 academic associates, 1 research fellow and 6 technical staff. A foundation Chair of Meteorology is expected to be filled by early 1979. Some 5 members of the Glaciology Section of the Antarctic Division, Department of Science, are permanently seconded to the Department. Most of the 23 postgraduate students are part-time candidates from the Bureau. During the year 6 to 10 members of the Australian Antarctic Expedition join the Glaciology Section.

37.2.14 The research program includes: physical meteorology, including radiation in clouds, polar air-sea-ice interaction, and Antarctic energy budgets; synoptic meteorology, including southern hemisphere jet streams, cyclone and anticyclone tracks, and sea-surface temperatures; climatology, including Australian city climates, pressure patterns, Antarctic temperatures, and Antarctic sea-ice and climate; prediction and numerical modelling, including modification of the physics of the ANMRC-Bureau spectral model, verification techniques, and modelling of clouds, tropical cyclones, and climate; applied meteorology, including urban and air pollution meteorology; glacial meteorology, including glacial modelling, and glacial climate records. Other studies include rotating-tank models of the atmosphere, and computer-produced English language weather forecasts.

There is considerable collaboration with Commonwealth agencies, Flinders University, and the USA Cold Regions Research Laboratory. There is strong representation on international committees and programs.

Geophysical Fluid Dynamics Laboratory of the Department of Mathematics, Monash University.

37.2.15 The staff of seven comprises five academic staff and two technicians. There are also about eight postgraduate students. The research program includes: dynamical meteorology, including analytical and numerical studies of clouds, waterspouts, tornadoes, cyclones, and stratospheric waves; synoptic meteorology including diagnostic studies of extra-tropical cyclones; forecasting, including limited-area and statistical/dynamical models; geophysical fluid dynamics, including baroclinic instability, buoyant turbulent flow, and stratified withdrawal flow; and dynamical oceanography, including Southern Ocean circulation, oceanic heat fluxes, and coastal tides. There is extensive collaboration with ANMRC, DAP and DCP. Staff members serve on international committees.

Physics Department, University of Adelaide

37.2.16 The atmosphere research program involves about five academic staff and four technicians. There are six postgraduate students. The research includes lower atmosphere turbulence, acoustic radar, trace constituents of the lower atmosphere, radio meteor observations of upper atmosphere winds, and lidar studies of stratospheric and tropospheric aerosols. There is collaboration with CSIRO, the Ionospheric Prediction Service, and the Defence Research Centre, Salisbury.

Flinders University Institute of Atmospheric and Marine Sciences (FIAMS)

37.2.17 The staff comprises six academic staff (three meteorologists and three oceanographers), and two technical staff. There are six postgraduate students. The research program includes: physical meteorology, including radiation, heat fluxes, and wind-blown sand; dynamical meteorology, including sea- and land-breeze and valley winds, and airflow over mountains; climatology, including microclimate, and Adelaide climate; geophysical fluid dynamics, including boundary layer flow, and two-dimensional turbulence; applied meteorology, including urban and regional studies; and dynamical oceanography and limnology, including oceanic circulation and heat fluxes; coastal oceanography and tides in the Coorong and the Gulf of St Vincent; limnology of the Lower Murray Lakes and Lake Eyre, and fluxes below the Ross Ice Shelf.

Climatology/Meteorology Sub-group of the School of Earth Sciences, Macquarie University

37.2.18 The staff comprises 1 professor, 5 academic associates and 4 technicians. There are 11 postgraduate students. The research program includes: urban meteorology, including Sydney's ozone, oxidants, turbidity, winds, inversions and climate; applied meteorology including

estimations of evaporation rate, dispersion of air pollution, and climate; and synoptic meteorology including surface winds and jet streams.

Tropical Research Unit in Meteorology and Atmospheric Physics (TRUMAP). James Cook University, Townsville

37.2.19 The staff comprises one professor, two research associates and the full-time-equivalent of one technician. There are two postgraduate students. The research program includes: acoustic sounding, turbulence, and electrical and magnetic properties of the atmosphere; radar meteorology and oceanography; synoptic meteorology of tropical cyclones; and climatology.

Other universities

37.2.20 Most other universities have Departments of Geography, Mathematics, Physics, Environmental Sciences, and Engineering involved in one or more aspects of atmospheric sciences research. The groups vary in size from 1 to 6 academic staff.

Colleges of advanced education

37.2.21 Staff at the colleges devote less than a quarter of their efforts to research. Colleges in nearly all states are involved, with an emphasis on radar and satellite meteorology. The Western Australian Institute of Technology makes the largest contribution, with 12 staff and 5 postgraduate students.

STATE GOVERNMENTS

37.2.22 There is relatively little atmospheric research in State government departments and instrumentalities. Most overlap with other disciplines in mission-oriented agencies for urban planning, pollution, agriculture, water resources, beach protection and the like. The New South Wales Pollution Control Commission, the Victorian State Electricity Commission, the Western Australian Public Health Department and other environmental, planning, and service instrumentalities have research projects in urban and air pollution meteorology with the aggregate research effort estimated as the equivalent of three to five full-time scientists. A small research effort in agricultural and forest meteorology and climatology is similarly dispersed amongst a number of State government departments of agriculture, and bodies such as the Forestry Commission of New South Wales. The other main area of applied meteorological research embraces hydrometeorological problems such as rainfall climatology, evaporation, evapotranspiration and development of the use of satellite and other remote sensing techniques for determination of hydrometeorological parameters. Most State water authorities are engaged to a limited degree. The Soil Conservation Service of New South Wales (raindrop spectra, precipitation climatology), the Soil Conservation Authority of Victoria (evapotranspiration, rainfall-runoff relationships), the Engineering and

Water Supply Department of South Australia (surface water balance, evaporation, evapotranspiration) and the Western Australian Main Roads Department are among the most active in this area.

THE PRIVATE SECTOR

37.2.23 The number of private meteorological organisations is not more than 12 and few of these could be regarded as undertaking significant supporting or ancillary research. Cameron McNamara and Partners in Queensland (hydrometeorology, rainfall climatology, radar meteorology), R.K. Steedman and Associates in Western Australia (regional climatology, studies of offshore winds and waves), the Horace Lamb Institute in South Australia (regional wind studies, influence of the Australian continent on air movement, mean sea level relationships over the Southern Ocean) are the main groups involved. A few other organisations and individuals are also engaged in research in the private sector, motivated by such factors as community need (e.g., Northern Rain Seekers, a group of graziers engaged in rain making experiments in Western Australia) or the desire to develop or prove new approaches to long-range forecasting. Up to half a dozen individuals with varying backgrounds are involved.

PUBLICATIONS

37.2.24 Almost every organisation produces internal research and technical reports, the Bureau of Meteorology being by far the most active. In addition, the Bureau has for 25 years published the Australian Meteorological Magazine. The CSIRO Divisions of Atmospheric Physics and Cloud Physics, and the ANMRC sustain high rates of publication in the major, refereed, international scientific journals.

SUMMARY

37.2.25 The Bureau is pre-eminent in Australia in the development part of R&D in the atmospheric sciences. The DAP has a high international reputation for research, earned originally in boundary layer meteorology, but now extending into several other areas. The DCP also has a high international reputation for research in its specialised area. The growing reputation of the much younger ANMRC is evidenced by the adoption overseas of the ANMRC spectral and limited area models. The other sectors (tertiary education, State and private) contain very small, isolated groups including individuals with ability, and often with international reputations. These small groups co-operate but are seldom able to achieve the level of effective interaction that is normal in large laboratories.

37.3 DESCRIPTION OF MAJOR R&D PROGRAMS

37.3.1 This section is a broad survey of the main Australian research in the atmospheric sciences in terms of the program categories defined in paragraph 37.1.5. It should be remembered that these categories are not mutually exclusive and that the assignment of individual research projects to a particular category has in some cases been arbitrary.

PHYSICAL METEOROLOGY

37.3.2 The major areas of research are: micrometeorology, which has led to significant applications in water resource management, agriculture, and many other environmental and industrial contexts; boundary layer studies including atmospheric turbulence and air-sea interaction; cloud micro-physics, dynamics, and seeding, and weather modification experiments; and solar and terrestrial radiation, and remote sensing. The main objective is a better understanding of weather (as distinct from the broad scale flow) and climate. However some further requirements are evident: for weather studies, understanding of the processes of the meso-scale (of the order of 100 km) must be strengthened; for climatic studies, research on cloud-radiation interaction must continue to grow, and other underlying physical interactions must also be examined; work to upgrade the physical content of numerical models must continue.

DYNAMICAL METEOROLOGY

37.3.3 The major areas of research are: tropical and extratropical cyclones and tornadoes; the dynamics of single clouds and cloud fields; airflow over mountains; baroclinic instability, and heat and mass transfer through baroclinic waves. The research is at the fundamental, rather than the operational level.

ATMOSPHERIC CHEMISTRY

37.3.4 The major areas of research are: urban and global pollution, and the associated atmospheric chemistry, laboratory studies of gas kinetics and spectroscopy, and the evolution of the atmosphere. Urban pollution studies involve the measurement of gases and particles in the urban atmosphere, the chemical modelling of their transformations including ozone production, and the identification of sources and sinks of pollutants. Studies in global atmospheric chemistry are concerned with cloud formation, and the relationship of the global climate to the ozone layer in the stratosphere. There have been extensive studies of particle distribution and composition, cloud condensation nuclei, ice nuclei and stratospheric particles. Australia has a major program for monitoring carbon dioxide, ozone, fluorocarbons and nitrogen oxides in the southern

hemisphere. There are also studies of the photochemistry of ozone, stratospheric-tropospheric exchange, uptake of carbon dioxide by crops, deduction of historical atmospheric records from isotope ratios in tree rings, and studies of the exchange of nitrogen compounds with soils and the oceans. Work on gas kinetics has been carried out in conjunction with combustion studies. The evolution of atmospheric ozone and oxygen have been studied in conjunction with spectroscopic studies, in the laboratory, of the ultraviolet absorption of oxygen.

OBSERVATIONAL METEOROLOGY

37.3.5 The national R&D effort in observational meteorology is distributed amongst government, university and other institutions and is broadly aimed at the development of new or improved techniques for sensing the structure and properties of the atmosphere over a range of temporal and spatial scales. Major areas of activity include development of the use of satellite imagery for inferring atmosphere circulation patterns, the derivation of vertical temperature profiles, and surface and cloud-top temperatures; the development of centimetric radar for tropical cyclone detection and areal rainfall estimation; the use of over-the-horizon radar for determination of state of the sea and low-level wind fields; the development of acoustic radar for probing the wind and temperature structure of the lower troposphere; and the use of lidar for remote sensing of atmospheric structure. Other major fields of work are associated with the development of drifting buoys for use during the First Global Atmospheric Research Program Global Experiment in 1979 and the installation of ground receiving facilities for the Japanese geostationary meteorological satellite launched in mid 1977.

37.3.6 Observational methods for measuring atmospheric constituents such as carbon dioxide have been improved by Australian development. An observational program is being developed at the Australian Baseline Air Pollution Station at Cape Grim in north-western Tasmania. Smaller-scale development of a wide range of observational equipment and techniques is dispersed through many firms and institutions. This development has produced, for example, improved pyranometers and instrument parachutes, and techniques for measuring electrical and magnetic effects in tropical cyclones.

SYNOPTIC METEOROLOGY

37.3.7 The main aim of Australian research in synoptic meteorology is to gain an increased understanding of the large-scale atmospheric circulation systems (cyclones and anticyclones, jetstreams, monsoon circulations,) over the southern hemisphere, and in particular over the Australasian region. The research is carried out mainly in the Bureau and ANMRC, and is directed towards the study of weather systems affecting operational weather forecasting in the Australian region.

37.3.8 The program covers descriptive and diagnostic studies of particular weather systems, the improvement of the techniques and models used in synoptic analysis, and synoptic climatological studies employing satellite and conventional data in addition to archival operational data. Despite its operational significance, synoptic meteorology has been somewhat neglected in recent years. Although the Bureau of Meteorology has continued to prepare and publish case history descriptions of major events, and its operational forecasting staff undertake some research as opportunities present, the systemisation of knowledge of Australian weather systems has not kept pace with either the need or the opportunities provided by access to new sources of data.

CLIMATOLOGY

37.3.9 Climatological research in Australia has extended to most of the normally accepted areas of the subject, but the expertise tends to be directed towards two extremes of possible research activity. For example, climate prediction has been attempted using either purely statistical techniques, or purely dynamical techniques (the so-called numerical 'general circulation models'). Neither has been very successful. There is limited activity in the middle ground of physically-based analyses of statistical properties of the atmosphere-earth-ocean system, but much of this is of a descriptive nature.

37.3.10 The emphasis has been on extreme time scales also, the short and the long, both regarding the physical basis of climate and the assessment of climatic impact. Agricultural activities have provided the main impetus for research into shorter time scales (extended-range weather prediction), while dendrochronologists, demographers, and others have been concerned with longer time scales. However, the 1-100 year time-scale is now being emphasised as economically relevant. There is a major weakness in climatic analysis on this medium time-scale, and strengthened research is needed in related studies (including statistical studies) of observed atmospheric behaviour, prediction, impact and the presentation of information. The same is true of research into processes which underlie climatic variability and change.

PREDICTION

37.3.11 Australian research on weather prediction is proceeding on two main fronts. The first is a descriptive, statistical and interpretive approach to the problem of understanding the behaviour of weather systems, and the quantification of observations in order to develop aids and techniques to assist in forecasting weather elements on scales ranging from clear air turbulence to major cyclones. The second approach is the improvement of physically-based, numerical models for deterministic forecasting of the broad-scale flow. Research has led to a gradual increase in skill for deterministic forecasting in routine operations in Australia. It is believed that a combination of the two approaches will carry the improvement through to the forecasting of actual weather events.

37.3.12 In Australia, considerable technological development is also under way in the field of prediction. Two main thrusts include a gradual automation of the forecasting of in-flight conditions for aircraft, and preliminary development of systems designed to automate the non-professional parts of the duties of operational forecasters.

APPLIED METEOROLOGY

37.3.13 In fields where Australian research groups have specialised, the applications and the associated investigations have been covered in depth. In other areas, investigations in applied meteorology are generated in response to community needs and to requests for meteorological advice or information. Enquiries over the widest range are received and handled by the Bureau of Meteorology; the CSIRO Divisions, while generally excluding synoptic and defence problems, have also contributed widely to this type of applied work.

37.3.14 Australian research in agrometeorology has achieved a world standing, largely due to fundamental work over 25 years in the Division of Atmospheric Physics. However, research in this field has been scaled down substantially over the past decade.

37.3.15 Research in air-pollution meteorology in Australia has been rather limited, although in recent years many organisations have become involved in particular aspects of the problem. This effort, too, has been based in part on fundamental work on turbulence and low level wind structure undertaken earlier in CSIRO.

37.3.16 Present R&D activity in aviation meteorology is limited in scope and concerned mainly with the problems of thunderstorm and clear air turbulence, low level wind shear, and the development of improved systems for describing and predicting route, and terminal, conditions for aviation.

37.3.17 Research in fields such as biometeorology and forest meteorology is isolated and limited in scope, and tends to revolve around the efforts of a small number of individuals with interests in specific problem areas such as spore dispersal, meteorological factors in hay fever outbreaks and the like.

37.3.18 The Australian research effort in hydrometeorology, initially concentrated mainly in the Bureau of Meteorology, has diversified in recent years, partly due to the funding of university and other groups through the Water Research Fund which is administered by the Australian Water Resources Council. A relatively strong research effort in rainfall climatology and hydrological modelling exists in Australia, and a fair amount of fundamental work on evaporation and evapotranspiration has been undertaken by CSIRO and university groups.

37.3.19 A relatively strong, if widely dispersed, effort exists in urban meteorology. This has been fostered by the recent trend toward

environmental impact analysis and the emphasis on planning aspects of new city developments. A conference in February 1977 held at Macquarie University and sponsored by the Royal Meteorological Society, showed that the national effort involved a surprising diversity of organisations. These included a number of university engineering departments, State planning bodies and private consultants as well as relevant CSIRO Divisions and the Bureau of Meteorology.

OCEANS AND ICE

37.3.20 Physical oceanographic research in Australia continues to be fragmented and in view of the importance of an understanding of the ocean circulation to problems of weather and climate, a strong case can be made for more support for this field. Just as ocean-atmosphere interaction is important to a host of atmospheric problems and phenomena, so too is the interaction of ice surfaces such as the Antarctic plateau with the overlying atmosphere. Some aspects of glacial meteorology are well developed in Australia, but the overall research effort in Antarctic meteorology is weak.

UPPER ATMOSPHERE SCIENCES

37.3.21 Upper atmosphere research in Australia is currently directed to a wide range of problems of the stratosphere, mesosphere, thermosphere, ionosphere and magnetosphere. Over 15 institutions conduct such research in Australia and its Antarctic Territory, using a variety of ground-based, balloon, rocket and satellite techniques. The research is aimed at understanding the impact of solar electromagnetic and corpuscular radiations on the earth's atmosphere, in addition to the tidal forces of the sun and moon.

37.3.22 Much current research requires vertical rocket soundings of winds, temperature, composition and pressure as a basis for studying various physical processes. The thermodynamics and chemical kinetics of the stratosphere and mesosphere are dominated by minor constituents (especially ozone and carbon dioxide) rather than the major ones, and it is therefore essential to understand in detail the chemical reactions of minor species.

37.3.23 Ionisation in the high atmosphere, above 50km altitude, is being used in Australia to study the dynamics of the region, and processes in plasma physics, such as the formation and movement of irregularities. The most important applications are to communications and defence operations. Both radar and lidar are contributing to an understanding of the fine structure of the ionosphere.

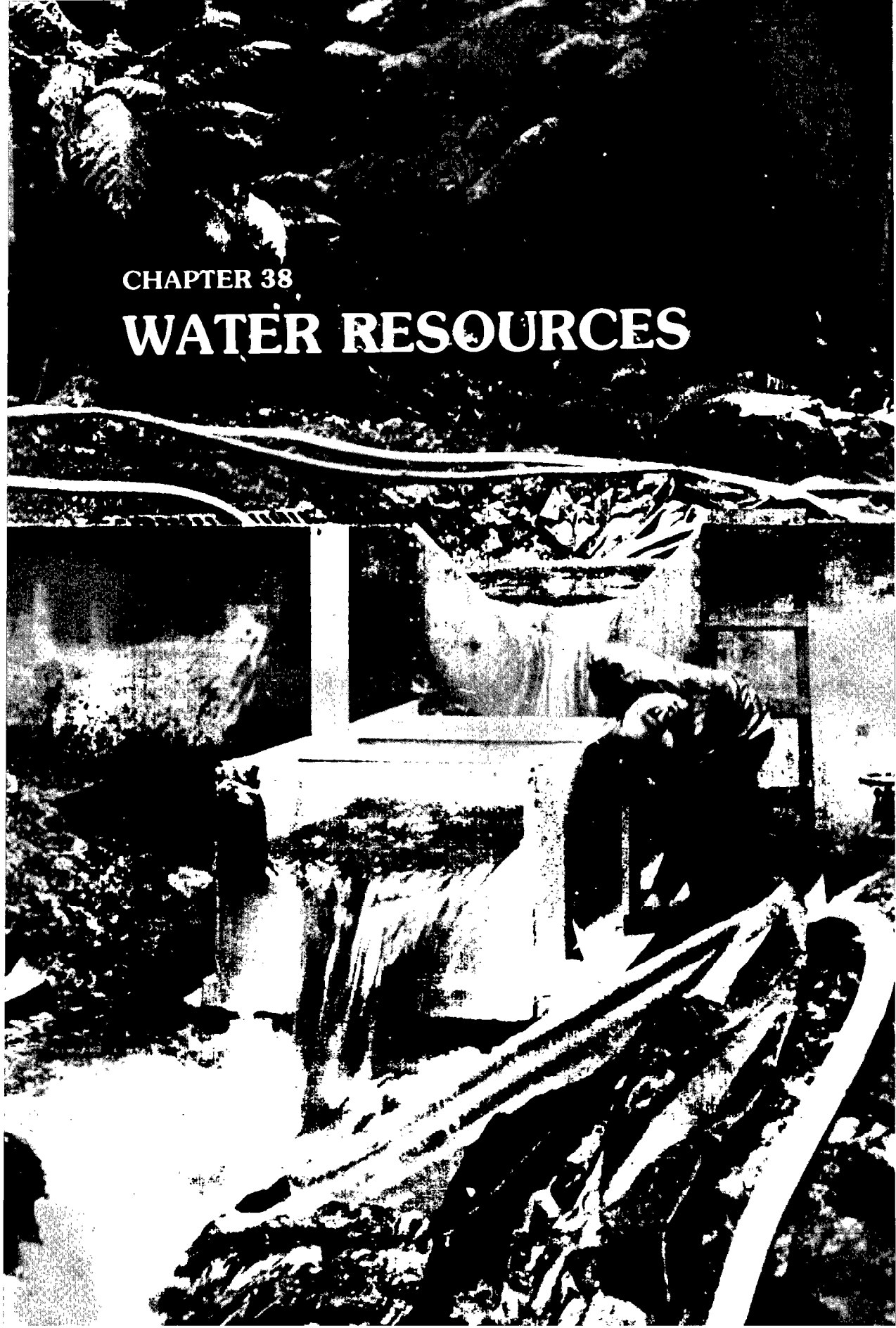
37.3.24 It is estimated that Australia has between 50 and 100 scientists of PhD standard working in the area of upper atmosphere physics at 9 universities and 5 government laboratories. Much of the work is associated

with the program of co-ordinated global research under the International Magnetosphere Study (IMS) conducted by the Special Committee on Solar Terrestrial Physics (SCOSTEP) of ICSU.

37.3.25 Australia will be expected by the International community to play a significant role in the Middle Atmosphere Programme (MAP) of SCOSTEP which is at present being planned. The MAP will involve detailed study the region 10-100 km altitude in the early 1980's. The coupling between the lower and upper atmosphere is of the utmost importance, and upper atmosphere physicists are now becoming interested in possible effects of the upper atmosphere on the lower atmosphere, including effects on the weather and climate.

CHAPTER 38

WATER RESOURCES



Photograph: Calibration of the Myrtle 2 Weir using a portable flume in the North Maroondah experimental area.

(Photograph courtesy Melbourne and Metropolitan Board of Works).

CHAPTER 38

WATER RESOURCES

38.1 BACKGROUND

INTRODUCTION

38.1.1 This Chapter describes R&D in the area of water resources and directly-related matters such as the hydrologic cycle, water assessment, conservation and augmentation, water quantity and quality management, water resources planning, water resources data and water engineering works. Some details of the three major sectors of water usage (municipal and industrial, crop irrigation, and other rural use) are covered. There is much research which is concerned with water in physical, chemical and biological processes in relation to the behaviour of soils, growth of plants, animal and human functions, industrial processes and so on. These are not discrete areas and R&D concerned with water in these processes is often not separately identifiable, as it forms part of a wider research program. For this reason, it is not easy to obtain a clear picture of the total effort and effective co-ordination is very difficult.

AUSTRALIA'S WATER RESOURCES

Key features

38.1.2 Australia's water resources are limited and unevenly distributed over the country. In addition, water availability is highly variable. Rainfall varies considerably from place to place, from season to season and from year to year, placing significant constraints on management of the country's water resources. Australia is popularly known as the 'world's driest continent' - a judgement that can be made on the basis of a comparison of the average annual run-off over the total land area of Australia with that of other large land masses, and, for example, the fact that the total precipitation received is only about one-fifth of that of the USA which has a similar surface area. However, such an evaluation suffers the limitations of all simple descriptions of complex systems, and it is worth noting that the amount of run-off per head of population for Australia is almost twice that of the next highest continent, South America, and over four times that of Europe, Asia or Africa.

38.1.3 The key aspect of Australia's water resources is not the absolute quantity but rather the variability - both in terms of where it is and when it is available. There are few regions that do not experience extremes in availability compared with most other inhabited parts of the world. Most capital cities have experienced water shortages, very heavy rainfall and in some cases, flooding. All rivers of any significance can be said to have highly variable rates of flow, with, in general, the largest being the most variable.

General description

38.1.4 Australia is a continent with a land surface which is generally highly weathered and flat. Rainfall is least variable along the coastal fringes, especially on the populous south-east coast and in Tasmania. Elsewhere rainfall is more seasonally variable and northern Australia experiences monsoonal conditions and tropical cyclones which may cause extensive flooding in rivers that have little or no flow for most of the year. Inland, the continent is arid, and rain is sparse and infrequent.

38.1.5 In Australia, only a small proportion of precipitation subsequently becomes surface run-off. Much precipitation reaching the ground either evaporates or is transpired by vegetation. Some of the water infiltrates into the soil, where it is taken up by vegetation, or percolates underground. Ground-water may reappear on the surface at springs and this, augmented by seepage through river banks and beds, comprises the base-flow of streams. The bulk of surface run-off flows to the sea. The remainder flows inland and is either dissipated by evaporation or infiltrates to ground-water storage. The development of Australia's water resources is tied closely to patterns of rainfall and run-off.

38.1.6 Australia is fortunate in having widespread occurrence of ground-water, particularly in arid and semi-arid areas. Ground-water derived from unconsolidated sediments, which are generally high yielding, is an important source of water for irrigation, industrial and domestic purposes. In addition, large sedimentary basins underlie 60% of the area of the continent; these include the Great Artesian Basin, which is amongst the largest in the world. Ground-water from this basin has sustained much of Australia's inland pastoral industry since the latter part of the nineteenth century.

38.1.7 In contrast to surface water, ground-water is more widely available in Australia; it is replenished by infiltration from rainfall and surface streams. Storages are generally large and flow rates slow. In the larger ground-water basins, water may remain in aquifers for very long periods ranging up to hundreds of thousands of years.

Use of water

38.1.8 Although Australia is often called the world's driest continent, domestic, municipal and industrial water consumption per head of population is comparable to that of other developed nations, and domestic water consumption in Australia, especially that used for watering gardens, is much higher than that in most other countries. This is despite the economic costs associated with the provision of water supplies in a hot, dry environment. Australia is a highly urbanised country with 80% of its population living in towns and cities which lie mostly on the temperate coastal fringes of the continent. Nevertheless, only about 15% of all water used is for non-agricultural purposes, most of the remainder being used for irrigation and stock watering. Irrigation is widely practised and, compared with other countries, Australia has one of the highest figures for irrigated area per head of population. Development in Australia has been greatly influenced by the nature and extent of available water resources, and with continued growth in demand, successful water management will require careful and co-ordinated planning based on adequate data and research.

38.1.9 The extreme variability of water resources and the difficulty in finding new sources to satisfy an ever-increasing demand emphasise the need for more efficient use of water, including increased re-use, and the need for developing more flexibility in both systems and patterns of use. There has been a general tendency to regard water as a 'free good' to be supplied in copious quantities at minimum cost; and a view that all water supply systems should be able to meet any demands placed upon them. Until recently, there has been no attempt to demonstrate the economic cost of these viewpoints. However, recent experience in Perth (and to a lesser extent in Adelaide and Melbourne) has led to a re-thinking of these views in the public mind. In two of these cities, the development of more realistic water-pricing schemes should, to some extent, encourage conservation of water in the future.

38.2 ORGANISATION, EXPENDITURE AND POLICIES

ORGANISATION

38.2.1 Under the Constitution, primary responsibility for the management of water resources rests with the States. The Commonwealth has similar powers to the States in its own territories, as well as overall responsibility for meteorology. While responsibility for water management lies with the States, a considerable proportion of State expenditure on assessment and research is provided by the Commonwealth with relatively small proportions provided for specific development projects. Research is undertaken by a variety of organisations but the most significant are

Commonwealth and State agencies together with tertiary education institutions. No single, national, water-research organisation exists, although a degree of co-ordination has been attempted by the Commonwealth and States, through the Australian Water Resources Council (AWRC), based on dissemination of information on water research through publications, catalogues and a network of committees with representatives drawn from most water agencies and some of the more important research institutions. Although the primary purpose of these committees is not research, they nevertheless perform a useful function in disseminating research results and in advising on priorities for research effort.

Commonwealth Government

38.2.2 The major part of the Commonwealth Governments' research activity is undertaken in several divisions of CSIRO. However, while water is an element in the research interests of these divisions, it is not the primary mission of any one of them. Other Commonwealth agencies undertaking water research include the Bureau of Meteorology, the Australian Atomic Energy Commission and the Bureau of Mineral Resources. Co-ordination of this research effort by the Commonwealth is limited to compilation of a biennial inventory of research (covering all water research in Australia) by the AWRC secretariat and a regular assessment of research effort based on this inventory leading to identification of gaps in key areas. There is no effective Australian equivalent of the United States Office of Water Research and Technology.

State governments

38.2.3 At State government level, most research activity is concentrated in State water authorities, geological surveys or mines departments, regional water and sewerage boards and environmental protection agencies. Research is also carried out by other agencies in areas such as agriculture, forestry, and fisheries, in which water management is directly related to the primary mission. In recent years there has been some co-ordination of research activities commenced at State level as evidenced by the formation of committees and other mechanisms to develop a broad approach to significant problem areas. A notable example is in Western Australia, where a concerted research effort is being directed toward the problems of land management and water quality in the Darling Ranges. This program is co-ordinated by a joint committee and involves CSIRO, several State water, and water-related, organisations and the University of Western Australia. In some other States, more formal arrangements have been initiated. For example, in Victoria, a Water Resources Council has been established, which consists of members drawn from all Victorian water authorities. It performs an important role in co-ordinating activities relating to water resources throughout the State. This includes some research and the Council is currently particularly concerned with research into all aspects of water re-use; it is also involved in flood plain management, and in education to encourage the conservation of water.

Tertiary education institutions

38.2.4 A considerable amount of water research is carried out in universities, colleges of advanced education and technical colleges. Apart from the basic requirements for staff and general laboratory and field equipment, these institutions are mainly dependent on external funds to support their research programs. Consequently these programs tend to reflect the concerns of their sponsors which include State government agencies, the AWRC (through the Commonwealth Government's Water Research Fund) and the Water Research Foundation. Additional sources of funds for basic work are secondment of staff from water authorities, Commonwealth Postgraduate Awards and grants from the Australian Research Grants Committee (ARGC).

Companies and Consultants

38.2.5 Consultants and private firms play a minor role in water resources research. The principal consulting organisations are the Australian Mineral Development Laboratories (Amdel) and the Snowy Mountains Engineering Corporation (SMEC), although several firms of engineering consultants have recently undertaken tasks which amounted to applied research in such areas as re-use of waste-water and harvesting of algae.

DATA REQUIREMENTS

38.2.6 Water resources R&D is highly dependent upon field data (as distinct from laboratory data), on rainfall, stream-flow and ground-water. It must rely on information from the large and expensive data collection operations by the Bureau of Meteorology (rainfall) and various State authorities (stream-flow and ground-water quantity and quality). These State programs (costing around \$16million per year) are assisted by tied Commonwealth grants now totalling approximately \$7million per year. Without this network of data collection bodies, water resources R&D could not continue. Exchange of information about methods of data collection and about the data itself is facilitated by the AWRC. Notable development of methods for the storage and exchange (in standard format) of hydrologic data on computer media has occurred, largely under the auspices of the AWRC.

EXPENDITURE

38.2.7 R&D, apart from fundamental research activities, is normally conducted as an adjunct to operational programs as a means of improving

techniques and methodology. Water-resources management in Australia is conducted almost entirely in the public sector and it is thus possible to obtain an estimate of expenditure on the management of water resources as well as that on water R&D. These figures are shown in Table 38.1.

TABLE 38.1

ESTIMATES OF EXPENDITURE ON WATER RESOURCES
MANAGEMENT AND R&D IN AUSTRALIA, 1976-77

<u>Item</u>	<u>Amount</u> <u>(\$million)</u>
Capital expenditure on development	900
Operation, maintenance and administration	700
National water resources assessment program	20
Resources research	12

Source: Based on aggregation of published information in annual reports and government budget papers. It is stressed that these figures are estimates only and are based on a simple aggregation of the best information available.

38.2.8 In Table 38.2 estimates are given for expenditure on water resources R&D. Total expenditure in 1976 was \$11.6million. The Commonwealth, principally through CSIRO, undertakes nearly half the water research in Australia, with State, local government agencies and tertiary education institutions undertaking most of the remainder.

TABLE 38.2

ESTIMATED EXPENDITURE ON WATER RESOURCES RESEARCH
IN AUSTRALIA, 1976

<u>Research Institution</u>	<u>Amount</u> <u>(\$million)</u>
Commonwealth Government	
- CSIRO	4.0
- Other	1.4
State and Local government	3.0
Tertiary education institutions	2.8
Industry	0.2
Private foundations	0.2
Total	<u>11.6</u>

Source Estimates based on an analysis of information contained in 'Inventory of Water Resources Research in Australia, 1976'[1].

NATIONAL R&D POLICY

38.2.9 In general there is no overall co-ordination of water R&D in Australia. The several organisations that have major responsibilities in this area pursue their own objectives, which in some cases are not primarily related to problems of water resources. Consequently any attempt to identify national research policy is confined largely to aggregating the policies of each of the major water research institutions.

38.2.10 The only attempt to co-ordinate activities at the national level has been undertaken through the Australian Water Resources Council (AWRC). This has been on the basis of assessment of current research, and the identification of areas considered to be of importance, but not currently covered, as areas of research priority. The AWRC, through a permanent research committee and specifically convened panels, compiles a national inventory of water research, identifies those current problems of water management considered to be national in extent and formulates a program of research to complement existing programs elsewhere. The Department of National Development then administers this program through a Commonwealth-funded Water Research Fund. In addition, through the AWRC, various essential support activities including publication of reports, information dissemination services, and seminars and workshops are arranged.

38.2.11 In the absence of a clear national focus for water research, stated national policy has been confined to the contents of the AWRC statement, 'A National Approach to Water Resources Management', which has been accepted by Commonwealth and State governments. Generally the statement sets national goals such as the provision of adequate water supplies, the multi-purpose management and re-use of water, the introduction of measures to ensure efficient use of water and the development of public education programs. As one means of implementing this program it is agreed that the Commonwealth and State governments will:

maintain a program of research, studies, dissemination of results, education and such other measures as may be required to enable the water management goals as set out in this Statement to be achieved [2].

Many of the objectives outlined in this statement are being pursued in current research programs; in the absence of a firm institutional base for national research effort, some are not being pursued effectively.

38.2.12 In addition to the AWRC, a number of other national organisations promote a national approach to some aspects of water research. The National Committee on Hydrology of the Institution of Engineers, Australia and of the Australian Academy of Science encourage research or dissemination of results of research into engineering and scientific hydrology respectively. National committees of international organisations such as the International Association for Water Pollution Research (IAWPR) and the Australian UNESCO Committee for the

International Hydrological Program (AUCIHP) perform similar functions in other areas.

38.2.13 Probably the most important aspect of the activities of these national organisations, and of the AWRC, is the wide-ranging membership of their respective committees. This is sufficiently broadly-based to enable considerable interchange of ideas across organisational and State boundaries. Membership ranges in many cases from senior management to expert technical staff. The discussion of common problems and the sharing of experience in the application of research results which occurs as a result of this interchange is an important and effective informal means of developing a national approach to water research.

38.3 DESCRIPTION OF R&D ESTABLISHMENTS

COMMONWEALTH GOVERNMENT

38.3.1 The major Commonwealth research agency is CSIRO. As many as 14 of its divisions undertake water, or water-related, research but of this number, only 8 divisions are significantly involved in water research. Funds for water research within CSIRO divisions are generally drawn from the Organisation's own budget which is primarily provided by the Commonwealth Government. In some cases, CSIRO divisions work in close co-operation with State water and agricultural departments, while in others CSIRO research programs are carried on with little involvement by State water authorities. In all divisions, while the Chief has primary responsibility for determining individual programs undertaken by the division within broad guidelines established by the CSIRO Executive, individual scientists influence the direction and often the initiation of research. CSIRO is represented on the AWRC Standing Committee and also on several technical and research committees and accordingly participates, through the Council, in the development of national priorities for water research.

38.3.2 In support of its various functions the Bureau of Meteorology undertakes R&D into several facets of meteorology and hydrology of direct importance to water resources assessment and management. In all, the equivalent of six full-time professional officers are engaged directly in water studies in the Bureau's Head Office, with supplementary work being undertaken in Regional Offices; other related meteorological research, into such problems as drought, climatic variability and rainfall prediction is also being undertaken by the Bureau. The Director of Meteorology has served on the AWRC Standing Committee since its inception and representatives of the Bureau serve on subsidiary technical and research committees. The Bureau is involved jointly with the CSIRO in the Australian Numerical Meteorology Research Centre, whose principal function is the development of numerical-dynamic models of the atmosphere for forecasting and for studying weather and climate.

38.3.3 Water research at the Australian Atomic Energy Commission (AAEC) is undertaken by the Division of Chemical Technology, the Health Physics Research Section, the Isotope Division, and the Physics Division. Generally, programs relate to practical applications of nuclear technology undertaken in conjunction with State water authorities.

38.3.4 The Bureau of Mineral Resources, forming part of the Commonwealth Department of National Development, undertakes research of a hydro-geological and hydro-geophysical nature related to its resources assessment function. The Snowy Mountains Engineering Corporation, which is a Commonwealth, statutory, consulting organisation undertakes some water research as part of its activities.

STATE GOVERNMENTS

38.3.5 Water research activities in the States are generally the responsibility of the major water authorities (irrigation and water supply commissions and urban water supply and sewerage boards) together with State departments of agriculture, environment, fisheries, forestry, mines and health. Research stations or institutes are commonly associated with departments of agriculture and with soil conservation services. Much of the research activity is geared to the solution of immediate problems, the application of existing knowledge to specific problems, and extension work.

38.3.6 In NSW, the major organisations are:

- . The Water Resources Commission. The Commission is responsible for rural water supplies throughout the State and for the measurement, investigation and control of development of surface water and ground-water resources.
- . The Metropolitan Water, Sewerage and Drainage Board. The Board is responsible for urban water supplies, sewerage and drainage in the greater Sydney and Wollongong areas. It maintains a number of gauging stations in river basins near Sydney.
- . The Hunter District Water Board. The Board is responsible for urban water supplies, sewerage and drainage in Newcastle and the surrounding region. It is responsible for management of several water supply areas in the region.
- . The Department of Public Works. The Department administers the provision of water supplies and sewerage in country towns and undertakes flood mitigation investigations and associated works in many tidal rivers.

38.3.7 In Victoria, the main organisations are:

- . The State Rivers and Water Supply Commission. The Commission is the main organisation responsible for the assessment,

development and utilisation of surface water resources in Victoria, and itself administers a number of rural and urban water supply systems outside the Melbourne metropolitan area. The Commission is also responsible for the development and utilisation of ground-water resources.

The Melbourne and Metropolitan Board of Works. The Board is responsible for water supplies in the Melbourne metropolitan area and the assessment of water resources and water quality aspects of present and potential sources of supply. It maintains gauging and water quality stations on the Yarra, Upper Thomson and Aberfeldy Rivers, and on two tributaries of the Goulburn River. The Board also maintains 17 small forest-hydrology research catchments.

The Soil Conservation Authority of Victoria. The Authority gauges approximately twenty small catchments, ranging in area from about 1 to 500 ha, which are used for research purposes.

The Department of Minerals and Energy. The Department is responsible for the location and investigation of ground-water throughout the State.

The Ministry of Water Resources and Water Supply. This Ministry was established to co-ordinate, and to advise the Minister on all matters pertaining to water resources, waste-water and drainage.

38.3.8 In Queensland, the main organisations are:

The Irrigation and Water Supply Commission. The Commission has major responsibility for the allocation of the State's water resources. It has the duties of measurement, assessment, development and management of the State's surface and underground water supplies, and in the case of the latter, receives assistance from the investigation programs of the Department of Mines.

The Department of Mines. The Department undertakes field investigations and measurements of the ground-water resources of Queensland in association with the Irrigation Commission.

The Brisbane City Council. The Council is responsible for water supplies to the Brisbane metropolitan area.

The Department of Local Government. The Department oversees local authority, water-supply undertakings, and arranges investigations of water supplies for local authorities. The Water Quality Council of Queensland is established within this Department.

38.3.9 In South Australia, the main organisations are:

The Engineering and Water Supply Department. The Department is responsible for all stream gauging work and for the investigation, development and management of water resources in South Australia.

The Department of Minerals and Energy. The Department is responsible for investigation and measurement of ground-water resources in South Australia.

38.3.10 In Western Australia, the main organisations are:

The Public Works Department. The Department is responsible for the development of both surface and ground-water resources in the greater part of the State. It carries out virtually all stream gauging in the State, and some ground-water investigation.

The Metropolitan Water Supply, Sewerage and Drainage Board. The Board is responsible for water supplies to the Perth metropolitan area. It carries out investigations on underground water, but relies on the Public Works Department for stream gauging.

The Department of Mines. The Department is responsible for the investigation and assessment of the State's ground-water resources. It also advises on ground-water problems.

38.3.11 In Tasmania, the main organisations are:

The Rivers and Water Supply Commission. The Commission exercises general control over the utilisation of Tasmania's water resources and is one of two authorities responsible for carrying out stream gaugings in the State.

The Hydro-Electric Commission. The Commission's principal functions are to generate and to supply electricity to Tasmanian consumers. As part of these functions, the Commission maintains and operates an extensive stream gauging network and is responsible for the operation of most major dams and reservoirs in the State.

The Department of Mines. The Department is responsible for investigation and measurement of ground-water resources in Tasmania.

38.3.12 In the ACT, responsibilities for water resources lie with the National Capital Development Commission and the Department of the Capital Territory, while the Northern Territory Department of Transport and Works is responsible for the overall assessment, development and control of surface and ground-water resources in the Northern Territory.

LOCAL GOVERNMENTS

38.3.13 Significant research effort in the local government sector is confined to the major urban water supply and sewerage boards which have been covered in the preceding section. Most other local government undertakings are not of a sufficient size to support research. Possibly as a result of this, they are generally offered little opportunity for involvement in the development of R&D programs. A great deal of development work for local governments is performed by consultants.

TERTIARY EDUCATION INSTITUTIONS

38.3.14 While most tertiary education institutions offer courses in all or many aspects of water resources, only some have particular expertise and significant programs in water research. However, with the recent recognition of the wide spectrum of water problems covering such diverse disciplines as medicine, law, economics, biology and chemistry in addition to the more traditional ones of engineering, geology and geography, more institutions have developed water-related research programs. In most cases these programs reflect the interests of one or two individual staff members and only rarely do they reflect an institutional commitment. The University of NSW and Monash University may be cited as examples of the latter.

COMPANIES AND CONSULTANTS

38.3.15 While some limited research activity occurs in this sector, it is almost always closely associated with operational activities or is being carried out for a client or one of the previously listed groups.

38.4 DESCRIPTION OF R&D PROGRAMS

38.4.1 There are no major R&D programs on water resources in Australia at present on the scale of some that are being carried out in the United States, Canada and the United Kingdom. This situation arises partly because of Australia's geography and partly because of the political structure of the country. In the 1950's there was a rapid increase in R&D related to quantitative aspects of water resources, but this has levelled out in the last two decades.

38.4.2 In recent years there has been a small but significant increase in management-oriented R&D activities. Since the mid-1960's there has been a steady increase in R&D work on water quality. The material presented in this section is largely based on research information contained in the

'Inventory of Water Resources Research in Australia 1976'[1]. The classification is that adopted in Australia by the AWRC and is the same as that used by the US Federal Council for Science and Technology.

WATER CYCLE

General

38.4.3 A large amount of research, including the AWRC Representative Basins Program, is being undertaken in this sub-category. Major projects investigating the effects of catchment management on water yield and quality are being undertaken by CSIRO Divisions of Land Use Research, Land Resources Management, Forest Research and of Plant Industry, and by forestry commissions and soil conservation authorities in a number of States. The Australian Atomic Energy Commission (AAEC) is investigating the application of nuclear techniques to studies of ground-water, rainfall, surface water and sediment transport in many parts of Australia. Considerable effort is being devoted to the estimation of characteristics of floods, and of selected probabilities of occurrence, for design purposes at two universities (Monash and NSW) using non-linear procedures for estimating the hydrograph. A number of authorities are investigating mathematic rainfall-runoff models. These include the CSIRO (which is developing models for the Representative Basins Program), the Bureau of Meteorology (which is working on models for forecasting floods), some state and major local water authorities and the University of NSW, Monash University and the Snowy Mountains Engineering Corporation (SMEC). A group at the University of NSW is looking at the possible extrapolation of the results from small experimental catchments to larger catchments.

Precipitation

38.4.4 The Bureau of Meteorology, CSIRO and the Australian Numerical Meteorology Research Centre are undertaking work on precipitation forecasting, rainfall climatology, patterns of storm rainfall and weather modification.

Evaporation and transpiration

38.4.5 A considerable amount of work is being carried out in this area, the principal contributors being the Bureau of Meteorology, CSIRO and agricultural agencies in South Australia and NSW, often in conjunction with university workers. The AWRC project on the field study of evaporation represents a large co-operative effort in this area. Much of the work being carried out relates to the productivity and water uptake of irrigated crops, although evapo-transpiration from natural grassland and pine forests is also being studied. The Engineering and Water Supply Department of South Australia is studying evaporation, seepage and evapo-transpiration from the River Murray, and the State Rivers and Water Supply Commission of Victoria is working on evaporation from shallow water tables.

Ground-water

38.4.6 Major, regional, ground-water studies, incorporating predictive mathematical models, are being carried out by the BMR (Great Artesian Basin), South Australian Department of Mines (Mt Gambier plain) and several other State agencies. The applicability of measurement techniques based on levels of natural isotopes to the determination of the age and mixing of ground-waters, of aquifer characteristics and of sources of recharge are being investigated by the AAEC and the CSIRO Division of Soils. The effects of bauxite mining on the ground-water hydrology of the Darling scarp area of Western Australia is being investigated by the Western Australian Government in conjunction with Alcoa of Australia Ltd. Several universities are studying ground-water flow processes.

Water in soils

38.4.7 The University of NSW is carrying out studies on the movement of water from recharge channels and pits. Other universities are undertaking research in association with postgraduate training in this area. Other major programs of research are being undertaken by the CSIRO Divisions of Soils, Environmental Mechanics, and Tropical Agronomy and some work is being carried out by state agencies.

Lakes

38.4.8 Work is being carried out by government agencies and research institutions on natural and man-made lakes in the fields of hydrology, biology, limnology, ecology and chemistry. Major studies are being undertaken on water impoundments in NSW (Department of Fisheries), and natural lakes in Tasmania, in addition to studies on lakes in South Australia and the ACT.

Chemical processes

38.4.9 This includes R&D on chemical interactions between water and its natural environment and the chemistry of precipitation. By far the largest amount of research work in this area is being carried out in universities, and the research is essentially project-oriented, hydro-chemical investigations of streams, lakes and estuaries. The CSIRO Division of Mineralogy is investigating heavy-metal interactions with sediments and the factors governing their solubility in natural waters. The AAEC is undertaking mathematical modelling studies of chemical speciation and of soil-water interaction. Laboratory and field data are being collected as inputs to the models.

WATER SUPPLY AUGMENTATION AND CONSERVATION

Saline water use

38.4.10 Research into the further development and evaluation of the Sirotherm process for the desalination of brackish water is being carried out jointly by the CSIRO Division of Chemical Technology, ICI Australia Ltd and the Australian Mineral Development Laboratories (Amdel). In addition, Amdel is continuously reviewing desalination methods developed overseas, especially their technical and economic performance and their potential for application to Australian conditions.

Water yield improvement

38.4.11 The Melbourne and Metropolitan Board of Works is investigating the relationship between vegetation and stream-flow performance at a number of mountain catchments. Projects on water harvesting from treated small catchments are being undertaken in the Western Australian and South Australian Departments of Agriculture.

Use of water of impaired quality

38.4.12 The principal research work being carried out is investigation of the effects of salinity and water-logging on plant performance by the CSIRO Division of Horticultural Research and the Victorian and South Australian Departments of Agriculture. The National Capital Development Commission (NCDC) is evaluating public acceptance, health, and cost aspects of reclaimed water use in the ACT, and the Victorian Ministry of Water Resources and Water Supply is leading a number of projects on water re-use in Victoria.

Conservation in industry and agriculture

38.4.13 Most research in this area is being undertaken by State departments of agriculture and the CSIRO. The work is aimed principally at improving irrigation efficiency through different irrigation methods and practices for various crop types. The University of New England is investigating irrigation developments in the Gwydir Valley (NSW). The University of NSW is investigating the economic feasibility of using sewage and other water of impaired quality as a heat-transfer medium.

WATER QUANTITY MANAGEMENT AND CONTROL

Control of water on the surface; ground-water management

38.4.14 A considerable amount of research work is being carried out, principally by State soil conservation, environment protection and agricultural authorities, but also by State water authorities and the CSIRO Divisions of Forest Research, Soils, and Land Resources Management. The work includes the effect of forestry, agricultural and soil conservation

practices on runoff quantity and soil loss. The State Rivers and Water Supply Commission of Victoria is developing a seepage meter and a handbook of standard operational techniques and is also investigating means of herbicidal control of aquatic weeds in irrigation channels. A study on aquatic weeds in Australia has recently been completed by the Department of Environment, Housing and Community Development. Several State water authorities and universities are investigating natural and artificial ground-water recharge, mostly in relation to irrigation areas.

Effects on water of man's non-water activities; watershed protection

38.4.15 Work on the effects of urbanisation and of forestry practices on the quantity and quality of runoff is being carried out by several universities, the NCDC, and State forest services. Monash and Macquarie Universities and the University of NSW are undertaking research into various aspects of the hydrologic effects of urbanisation. The Rivers and Water Supply Commission of Tasmania, in conjunction with the Tasmanian Department of Environment, is investigating the effects of woodchip operations on soil erosion and on the sediment load of streams in Tasmania.

WATER QUALITY MANAGEMENT AND PROTECTION

Identification of pollutants

38.4.16 Research into techniques of analysis for physical, chemical and biological pollutants is being carried out by the Australian Atomic Energy Commission (AAEC) and the National Biological Standards Laboratory (NBSL). Several projects, involving particular methods of laboratory analysis, are being carried out by universities.

Sources and fate of pollutants

38.4.17 Research is being undertaken by the AAEC, the Bureau of Mineral Resources (BMR), the CSIRO Division of Irrigation Research, State water authorities and environmental agencies, and tertiary institutions. Several large regional investigations of surface or ground-water pollution are being undertaken at Mt Gambier, the Latrobe Valley, the Gippsland Lakes, Port Phillip Bay and Moreton Bay. Pollutants under study include heavy metals, nutrients, leachates from sanitary landfills, herbicides, dissolved salts and others.

Effects of pollution

38.4.18 Research is being undertaken by the AAEC, the CSIRO Divisions of Fisheries and Oceanography and of Irrigation Research, State water and environmental agencies and tertiary institutions. Much of the research relates to the effects of heavy metals and pesticides on aquatic fauna, but the effects of discharges of heated water and industrial effluent, and of sewage disposal, are also being studied. Several research projects are investigating sources of eutrophication in man-made water storages.

Waste treatment processes; water treatment and distribution

38.4.19 Research is being carried out by the AAEC, the CSIRO Divisions of Applied Organic Chemistry, Environmental Mechanics, Chemical Technology, and Textile Industry, State public works departments and sewerage and drainage boards, Amdel and several universities. Treatment processes for industrial, agricultural and organic wastes are being developed. Research projects on sewage as a resource and the harvesting of algae from domestic sewage have recently been completed by the Department of Environment, Housing and Community Development, and the CSIRO Division of Chemical Technology is studying the algal treatment of sewage. The Public Works Department of NSW is investigating various methods for the removal of turbidity from water. The University of Melbourne is investigating the coagulation of colloidal matter by aqueous solutions of aluminium salts and metal ion adsorption at mineral-water interfaces.

Water quality control

38.4.20 Research on catchment management is being carried out by the CSIRO Division of Forest Research and State forestry and soil conservation authorities. The Engineering and Water Supply Department (E&WSD) of South Australia is investigating the management of the lower reaches of the River Murray. Artificial aeration and destratification techniques for improving reservoir water quality are being investigated in Victoria by the State Rivers and Water Supply Commission.

WATER RESOURCES PLANNING

Techniques of planning

38.4.21 The principal research work in systems analysis and probability studies in planning is being carried out by the CSIRO Division of Land Resources Management, the Snowy Mountains Engineering Corporation (SMEC), E&WSD (South Australia) and several universities. Linear and dynamic programming techniques and probabilistic reservoir yield analysis are being investigated at Monash University, the University of NSW, the SMEC and the E&WSD.

Evaluation process

38.4.22 The University of NSW and the E&WSD are carrying out research in this area. This includes flood plain management and mapping, philosophies and problems in estimating the characteristics of floods (of selected probabilities of occurrence) for design purposes, alternative water uses and the effects of inflation on investment in water supplies.

Ecologic impact of water development

38.4.23 There are many specific ecological surveys being undertaken by the CSIRO Division of Wildlife Research and by State agencies. A major study of the ecological impact of the Dartmouth Dam is being carried out by the State Rivers and Water Supply Commission (Victoria); the University of Western Australia is studying the ecology and epidemiology of the Ord River Dam area and in South Australia ecological changes as a result of a number of water developments are being investigated by the E&WSD.

RESOURCES DATA

Data acquisition

38.4.24 Substantial research programs are being undertaken by the Bureau of Meteorology and the CSIRO Divisions of Atmospheric Physics, Land Resources Management, and Mineral Physics. Included in these are projects of photogrammetric measurement of surface velocities in streams, assessment of hydrologic parameters using remote sensing techniques and the application of thermal scanning methods for detection of variations of moisture in surface soil.

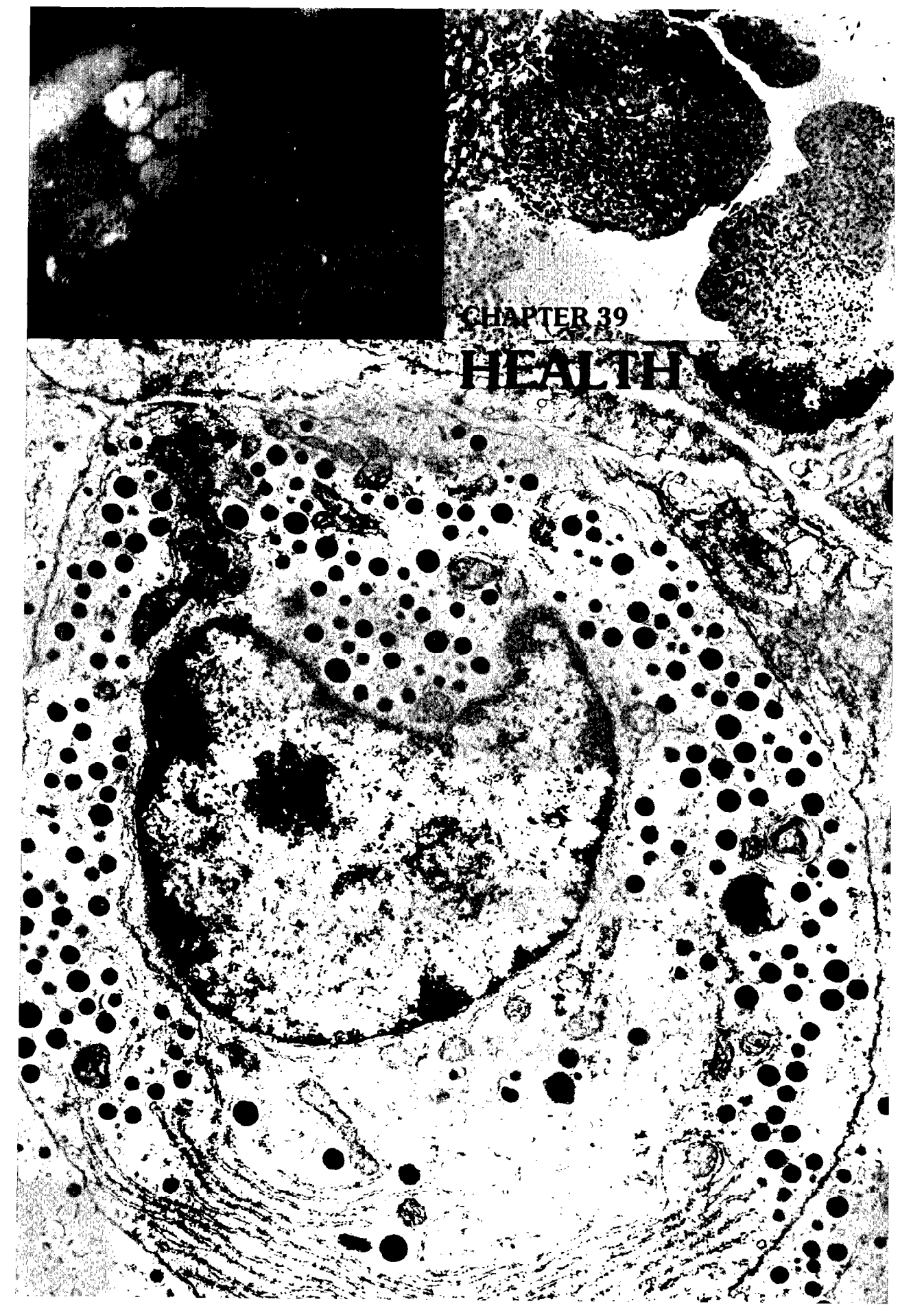
ENGINEERING WORKS

Soil mechanics; rock mechanics and geology; materials

38.4.25 Considerable research of wide applicability is being undertaken by the CSIRO Division of Applied Geomechanics. The State Rivers and Water Supply Commission of Victoria is undertaking investigations of rock weathering on dam slopes, and also on protective coating for mild steel pipes and on the deformation performance of underground plastic pipes. The corrosion behaviour of steel pre-stressing tendons is being studied by Monash University and a wide range of materials problems by Amdel.

NOTES AND REFERENCES

1. 'Inventory of Water Resources Research in Australia, 1976', Australian Water Resources Council, Department of National Resources, 1976; 137pp.
2. Attachment to Record of 20th Meeting of AWRC. Tabled in Parliament, 4 November 1977.

This is a high-contrast, black and white electron micrograph of a cell. The central feature is a large, roughly circular nucleus containing a dense, dark nucleolus. The cytoplasm is filled with numerous mitochondria, which appear as dark, oval-shaped structures with internal folds (cristae). The overall texture is granular and detailed, typical of electron microscopy. The text "CHAPTER 39" is overlaid on the upper right portion of the image.

CHAPTER 39

HEALTH

Photograph: Islet Cell Transplantation in experimental Diabetes Mellitus. The top left-hand photograph is a photomicrograph (magnification X10) of a pancreatic islet cell graft under the kidney capsule of a diabetic mouse. The top right-hand photograph is a light micrograph (X150) of a graft showing large islet cell clusters under the renal capsule. The graft was in situ for four months and ameliorated the diabetes produced in the recipient mouse by a previous injection of streptozotocin. The lower photograph is an electron micrograph (X20,000) of an insulin-producing islet cell.

(Photograph courtesy the Walter and Eliza Hall Institute of Medical Research).

CHAPTER 39

HEALTH

39.1 INTRODUCTION

39.1.1 This Chapter deals with research, whether fundamental or applied, directed towards the goal of health at individual and community levels. It encompasses research on the causation, prevention and treatment of disease as well as more fundamental studies on biological systems which need to be better understood before diseases affecting them can be treated. These areas, termed biomedical research, overlap to a significant degree with studies covered in Chapter 17 on Fundamental Research. Health research also embraces studies on social and economic aspects of the provision of health care, together with research, planning and evaluation concerning such provision. This field, not yet fully developed in Australia, is termed health services research.

39.1.2 Within the health research field there is a very wide range of individual disciplines. A classification of these disciplines, based on that of the National Health and Medical Research Council (NH & MRC), is attached as Appendix 39.1.

39.2 ORGANISATION, POLICIES AND FUNDING

POLICIES AND AGREEMENTS

39.2.1 The objectives of health research in Australia can be summarised as:

- . the continuing extension of basic knowledge concerning the functions of the human body, all aspects of disease, and environmental factors which contribute to ill health;
- . the development of new and improved knowledge concerning the prevention of ill health, cures for specific diseases, and methods of treatment for the alleviation of chronic conditions;
- . the development of new and improved knowledge concerning methods of delivery of health care, and the quality of, and the need for, such care.

the surveillance of innovations in health care that are reported in the overseas literature, and the maintenance within Australia of the capacity to assess such innovations and to enable new technology in the health field to be rapidly and efficiently transferred where desired.

39.2.2 Within these broad objectives, the various organisations, groups and individuals involved have much more defined objectives relating to specific areas. These may focus on any one of the above aspects or may involve a combination of more than one.

39.2.3 Health research derives its real impetus from the endeavours of first class investigators and institutions. For their efforts to be successful in promoting better health care, it is vital that a stable career structure and an adequate funding policy exist. Only in this way can the right of the individual research worker to select his/her field of study be assured while allowing some degree of flexibility in meeting the priorities as perceived by Government or the community, or both. The importance of flexibility and long-term planning in research is well illustrated in a recent article by Comroe and Dipps (Science, 192 (1976), p.105) who analysed the steps leading to the development of open heart surgery. Their conclusions were summarised as follows:

Our data show that clinical advance requires different types of research and development and not one to the exclusion of another. Thus the problem is not either-or, but a question of how much support to one type and how much to another. Our data compel us to conclude that basic research pays off in terms of key discoveries almost twice as handsomely as other types of research and development combined.

Thus open heart surgery became possible not as a result of target-orientated research, but due to the coming together of the endeavours of many individuals in basic research. Where 'direction' plays a role is in ensuring a clinical outlet for such discoveries and their effective application to patient care.

39.2.4 The value of health research should be measured in terms of its cost benefit to the community. On the other hand, funding policies need to be based on the realisation that the benefits accruing from basic research are not necessarily amenable to short term assessment. Indeed the impact of new discoveries may take years to be appreciated fully at the level of health care delivery. Previous research has led to the development of complex technologies which are both effective and costly. For example, the community is now benefiting from organ transplantation and the invention of artificial organs, yet the costs of this technology are high. The only long term solution to the problem of rising costs is acquisition of new information and the only source of such information is research. It is in this context that the phrase 'prevention is better and cheaper than cure' has its real meaning.

39.2.5 In general, the overall needs in health science, particularly in the biomedical research area, are reviewed by the National Health and Medical Research Council (NH & MRC), the principal funding body in the health research field, which advises the Commonwealth Government of areas where it considers additional funds or manpower are necessary. This information is published and is therefore available to the States and to the community generally. Close liaison on these matters is maintained between the Commonwealth Department of Health and the NH & MRC.

39.2.6 The NH & MRC has developed lines of co-ordination with certain other funding organisations in order to avoid duplication of support, and to rationalise the support being provided. For example, it meets on a regular basis with the Australian Research Grants Committee (ARGC) to identify applications which may be more appropriate to that body. The NH & MRC also maintains contact with the Department of Veterans' Affairs and with grant-giving organisations supported by public appeal such as the National Heart Foundation and the Australian Kidney Foundation. As a result, channels of communication exist which allow the translation of discoveries in basic research into clinical practice.

39.2.7 The main Commonwealth body responsible for advice to Government on, and funding of research in, the development and maintenance of health care delivery has, until recently, been the Hospitals and Health Services Commission (H & HSC). This Chapter records the activities of the H & HSC until its disbandment in early 1978, when its functions were taken over by the Commonwealth Department of Health.

ORGANISATION

39.2.8 Many organisations are involved in carrying out and funding health research in Australia. These include Commonwealth and State government departments and authorities, independent research organisations, universities and their associated teaching hospitals, institutes of technology, private charitable foundations, specific disease-related foundations such as the National Heart Foundation and the Australian Kidney Foundation, committees and councils, professional organisations, pharmaceutical companies, etc. As well, certain overseas organisations such as the World Health Organisation, the National Institutes of Health of the United States Department of Health, Education and Welfare, and the Ford and Rockefeller Foundations in the United States of America provide funds for health research in Australia.

39.2.9 Lastly, a great deal of what may be classified as developmental research is carried on by private individuals and private medical practitioners and some significant advances in research have been made by such individuals.

39.2.10 Most basic health research is conducted in universities and institutions, while most clinical research is carried on in universities and teaching hospitals. Other developmental research occurs in government

departments and institutions. Most research in health sciences is directed towards solving the problem of major diseases in man. This may take the form of an individual investigating basic mechanisms at the cellular level, or a multi-centre trial of a new drug, or any endeavour between these two extremes of fundamental and applied research.

39.2.11 Research into particular needs is stimulated by organisations with specific target areas. This includes organisations such as the National Heart Foundation, the Life Insurance Medical Officers' Research Fund, the Anti-Cancer Councils, the Australian Kidney Foundation, and the Asthma Foundation. These groups stimulate research in their particular area and provide funds for research. The National Health and Medical Research Council also encourages research in areas which have been determined as being of special need. The different research organisations do co-ordinate in the funding of research and in general. There is close liaison in the awarding of grants-in-aid to research institutes or units.

39.2.12 Because funds for health research are limited it is often necessary for research workers and research institutions and university departments to receive small grants from several different sources. This has meant some duplication of effort in applying for funds, as well as a duplication of effort in assessing such applications. Health research in the universities and their affiliated teaching hospitals is mainly carried out by departments and individuals who have been supported by the NH & MRC or specific grant-giving bodies. The grants are usually for a specific project and for only one or two years. The project often depends on key university personnel who hold permanent university appointments. The ancillary or back-up staff for such personnel is provided by the research funds and because of their short duration, the turnover in such positions is generally high. Similar arrangements exist in the teaching hospitals. There are very few long-term research units in departments of the universities. The Australian National University's John Curtin School of Medical Research is the only university-based organisation formally constituted for long-term pursuit of health research.

39.2.13 There are two major independent research institutes, the Walter and Eliza Hall Institute of Medical Research and The Howard Florey Institute of Experimental Physiology and Medicine, which receive substantial direct support from the NH & MRC on a five year 'block' grant basis. There are also several other private, large research institutes which include the Baker Institute, Kanematsu Institute, Garvan Institute, Kolling Institute and the Medical Research Centre at Prince Henry's Hospital, Melbourne. These institutes are generally devoted to a particular field of interest, and have a core group of senior research workers working within them. However, very few of them are on financially secure ground and all, apart from government funding, receive substantial funds from other organisations or bodies. There are also prominent research institutes attached to the major children's hospitals in Sydney and Melbourne. Much research, mainly of a developmental kind, is carried out in government departments and by private individuals and medical practitioners.

FUNDING

Overall level of research expenditure

39.2.14 Accurate up-to-date figures relating to expenditure on health research in Australia are not available. However, extrapolating from information which is available on total research expenditure by university medical and dental schools, and expenditure by major research institutes and government organisations involved in research, it is thought that overall expenditure on health research in Australia is of the order of \$40 - \$45million annually. This compares with a 1976-77 annual outlay on health care of about \$6,254million.

39.2.15 Funding of health research in Australia from all sources is low when compared with that of other countries with similar economic and social backgrounds. The situation in relation to the major overseas government agency supporting medical research, (i.e. the equivalent of NH & MRC) is set out below for 1973, which is the most recent year for which full comparative figures are available:

TABLE 39.1
INTERNATIONAL COMPARISON OF MEDICAL
RESEARCH FUNDING

<u>Nation</u>		<u>Medical Research Budget \$Amillion</u>	<u>Budget per Capita \$A</u>	<u>Budget as a % of G.N.P.</u>
USA	(1973)	1,548.6	7.70	0.246
UK	(1973)	43.3	0.78	0.059
Canada	(1973)	25.5	1.16	0.052
Sweden	(1973)	7.5	0.92	0.039
France	(1973)	34.9	0.67	0.037
W. Germany	(1973)	35.4	0.57	0.034
Australia	(1973)	4.8	0.35	0.013

39.2.16 Australia's expenditure increased between 1973 and 1977, as did that of other nations.

TABLE 39.2
INTERNATIONAL MEDICAL RESEARCH
FUNDING 1973 AND 1977

<u>Nation</u>	<u>Budget (\$Amillion)</u>			<u>Per Capita (\$A)</u>		
	<u>1973</u>	<u>1977</u>	<u>% increase</u>	<u>1973</u>	<u>1977</u>	<u>% increase</u>
Canada	25.5	41.1	62	1.16	1.76	52
France	34.9	70.0	100	0.67	1.32	97
Australia	4.8	9.2	92	0.35	0.66	89

However, these figures are considerably influenced by inflation, as illustrated by the following more detailed table of the Australian NH & MRC budget, 1973-77. The Australian Bureau of Statistics index for 'Economic Services - General Administration, Regulation and Research' has been used to convert current dollar figures into the 1973 equivalent.

TABLE 39.3
NH & MRC BUDGET, 1973-77

<u>Year</u>	<u>NH & MRC Budget</u>	<u>Equivalent 1973 \$</u>
	<u>\$million</u>	<u>\$million</u>
1973	\$4.8	4.8
1974	\$6.75	5.8
1975	\$7.10	4.83
1976	\$8.11	4.7
1977	\$9.2	4.78

This table shows that there has been no real increase in the NH & MRC budget since 1973.

Sources of funds for research

39.2.17 The major sources of funds for health research that are within the Commonwealth Government structure are the NH & MRC, the Department of Health, the Tertiary Education Commission, the Australian Research Grants Committee (ARGC), the Educational Research and Development Committee (ERDC), and Commonwealth organisations directly involved in research.

39.2.18 The NH & MRC is the principal funding body. It was originally constituted by Order in Council in 1936, and its present structure was determined by an Order of 30 April 1975.

39.2.19 The Council, which is under the Chairmanship of the Commonwealth Director-General of Health, comprises 24 persons including representatives of the Commonwealth and State Departments of Health, the Commonwealth Serum Laboratories Commission (CSL), medical organisations or colleges, consumers, the universities, and eminent lay people. The Secretary of the Council is a senior officer of the Commonwealth Department of Health.

39.2.20 The functions of the Council in relation to research are:

- to inquire into, advise and make recommendations to the Commonwealth and the States on medical research;
- to advise the Minister on the application of the Medical Research Endowment Fund for the purposes of the Medical Research Endowment Act 1973; and
- to advise and make recommendations to the Commonwealth on the expenditure of money on medical research and in connection with projects of medical research generally.

39.2.21 The Council operates three advisory committees, the Medical Research Advisory Committee, the Medicine Advisory Committee and the Public Health Advisory Committee, and a large number of smaller subcommittees. At present over 400 persons serve on the various committees. The inter-relationship between the Council and its committees is shown in Figure 39.1.

39.2.22 Research supported by the Council is funded from the Medical Research Endowment Fund established under the Medical Research Endowment Act to provide assistance:

- . to departments of the Commonwealth or of a State engaged in medical research;
- . to universities for the purpose of medical research;
- . to institutions and persons engaged in medical research; and
- . in the training of persons in medical research.

Grants from the fund are made upon the approval of the Minister for Health and on the advice of the Council.

39.2.23 These funds have been inadequate for the number of applications received and assessed as worthy of support. Furthermore such applications in Australia are now tailored to meet what is regarded as the likely amount of money available, and in most cases the grants are well below the money required to perform the particular research project.

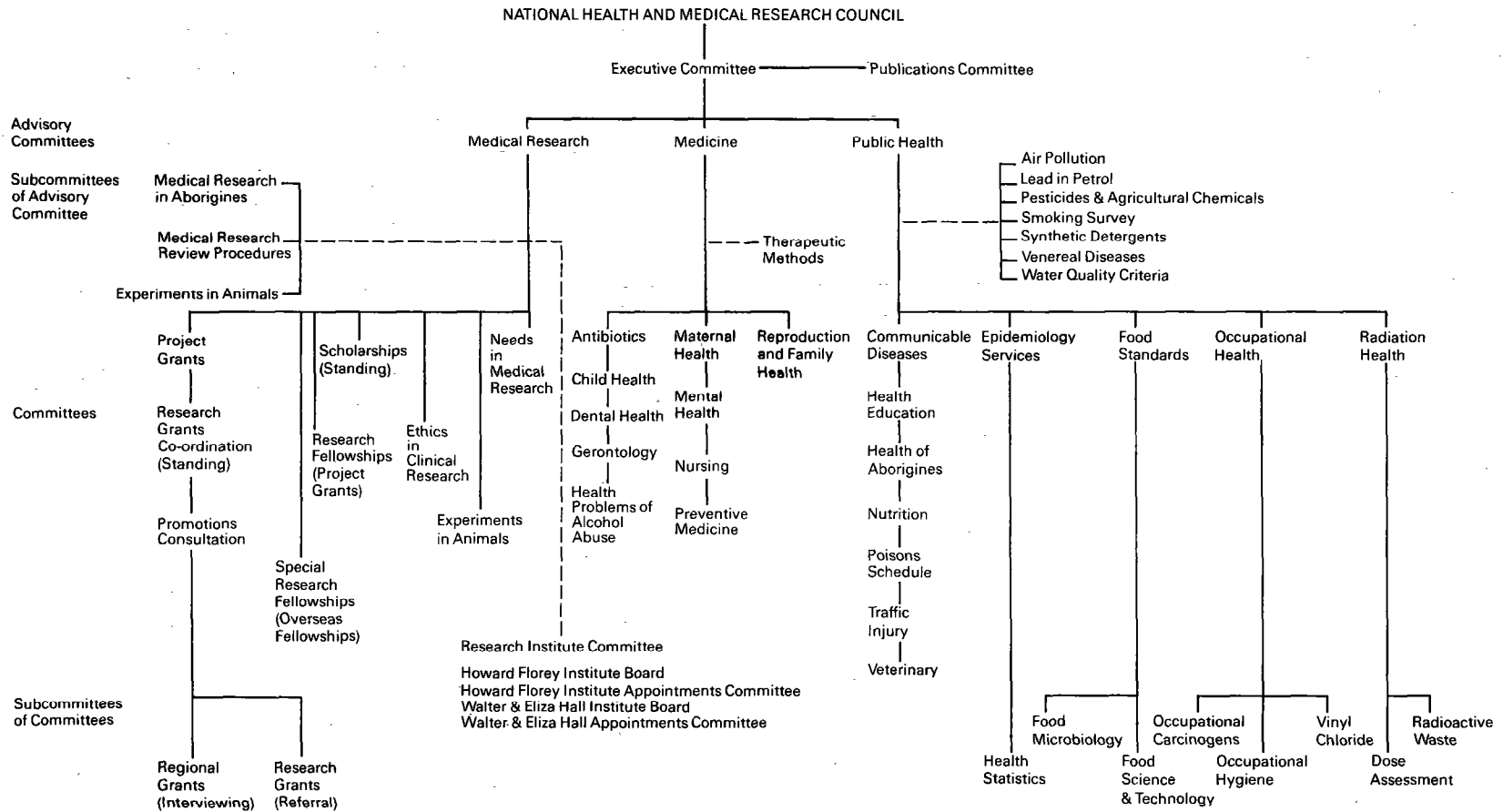
39.2.24 Support by the Council encompasses block grants to larger institutes, grants to special units, support of research projects, postgraduate scholarships and overseas fellowships. A system which reviews procedures and priorities on a continuing basis has been set up through the Medical Research Advisory Committee and its subcommittees. While the major portion of available funds continues to be awarded over the broad area of research and on scientific merit, the Council has in recent years attempted to fill perceived gaps in research effort by setting up small expert units in such fields as psychiatry, heart disease, and renal disease. It also encourages training in fields such as epidemiology and clinical pharmacology. New initiatives being developed include extension of this training scheme into other areas of applied and clinical research, and to include non-medical graduates.

39.2.25 Financial stringencies have made it impossible to implement all the proposed innovations, and forward planning has been made more uncertain through the recent introduction of rolling triennia. This uncertainty stems partly from the lack of a guaranteed triennial budget and from a lack of information on the acceptance by the Government of the Council's proposals for the second and third years.

39.2.26 Applications for Council support are evaluated and scientific merit assessed through a system of peer review which includes reports by Australian and overseas assessors, and interviews by co-opted specialist committees. The types of grants made by Council are set out in more detail in Appendix 39.2.

39.2.27 The H & HSC was, until its disbandment in early 1978, the major source of Commonwealth support for research and development in the areas

FIGURE 39.1
ORGANISATION OF THE NATIONAL HEALTH
AND MEDICAL RESEARCH COUNCIL



of health services planning, provision, evaluation and innovation, and the search for alternative methods of health care delivery. Its function was therefore distinct from that of NH & MRC which funds basic research, but by virtue of its links with NH & MRC, it contributed to the flow-on of new discoveries to the field of health care delivery.

39.2.28 The H & HSC, which was established in 1973, was responsible to the Minister for Health. It consisted of three full-time and up to nine part-time Commissioners appointed by the Governor-General. Its functions included ascertaining, and recommending to the Minister on, the health care needs of the Australian community and promoting, and taking part in, the planning of health services.

39.2.29 The Commission supported three major types of research initiative:

- . research and planning units in State health authorities (about 56% of the total annual appropriation);
- . research and evaluation by independent experts; and
- . research on national health priorities commissioned by the Commission.

39.2.30 The Commission's role in this area was primarily carried out through an Executive, four committees with oversight of the four broad research and evaluation subject areas and the Research and Evaluation Working Party. The latter was an advisory panel which advised the Commission on the approval of projects after considering the results of internal and external reviews.

39.2.31 The following allocations to the States and universities etc. were made by the Commission during its period of operation, under its Health Services Planning and Research Program:

TABLE 39.4

H & HSC ALLOCATIONS, 1973-74 TO 1976-77

<u>Year</u>	<u>State planning units</u> \$	<u>Universities & other bodies</u> \$
1973-74	181,032	140,227
1974-75	434,982	463,532
1975-76	500,000	349,732
1976-77	560,000	444,342

39.2.32 The Commissions's arrangements for support under the program were:

- . support on a \$2 for \$1 basis to States to develop and expand State research and evaluation units;
- . support by way of unmatched grants to universities and other bodies for independent research and evaluation of health care systems and for studies requested by the Commission.

39.2.33 Difficulties in obtaining appropriately developed research proposals led the Commission in 1976 to embark on a policy of commissioning studies in areas of concern. Since its disbandment, the H & HSC's functions have been taken over by the Policy and Planning Division of Commonwealth Department of Health. Organisation and development of project grants is through the recently established Health Services Research and Development Grants Advisory Committee of the Department.

39.2.34 A substantial amount of funding for health research carried out in universities and colleges of advanced education emanates from the normal grants made by the Tertiary Education Commission. However, the amount involved is difficult to determine.

39.2.35 The Tertiary Education Commission has provided the following details for the total, direct, research expenditure by all universities over the three years 1973-1975:

TABLE 39.5

UNIVERSITY DIRECT HEALTH RESEARCH EXPENDITURE 1973-75

	1973 (\$million)	1974 (\$million)	1975 (\$million)
All faculties	49.519	59.525	65.560
Faculties of Medicine and Dentistry only	10.344	12.507	14.724

An indication of the pattern of funding of research carried out by university faculties of medicine and dentistry is given by the summary of expenditure on research by the University of Queensland Faculty of Medicine and Dentistry for 1974-77, which is attached as Appendix 39.3.

39.2.36 Health research is, of course, conducted by faculties other than medicine and dentistry but information on health research expenditures within these other faculties is not available. No similar research expenditure information is available for colleges of advanced education.

39.2.37 The Australian Research Grants Committee has supported some biomedical research but since 1975 its policy has been not to support medical research as such. However, as noted above, demarcation between health research and fundamental biology is difficult. The ARGC supports considerable research in pre-clinical medical departments.

39.2.38 The Education Research and Development Committee (ERDC), which reports to the Minister for Education, funds research activities in education. The Committee has sometimes supported health-related research in the education field. Close liaison between the Department of Health and ERDC is maintained in the review of 'grey area' proposals, (e.g. in the area of evaluation of the impact of medical education programs on performance beyond graduation), to determine which of these each will support.

39.2.39 The Department of Health makes a substantial direct contribution to health research through activities of organisations with the Department. These include the Institute of Child Health, the School of Public Health and Tropical Medicine, The National Acoustics Laboratories, the Ultrasonics Institute, the Australian Radiation Laboratory and the Australian Dental Standards Laboratory. Expenditure on research forms part of the normal Departmental appropriation and is not separately identified.

39.2.40 The Department has, on occasions, made direct grants to research organisations in addition to those which it has made through grant-giving mechanisms such as the NH & MRC and the H & HSC. For example, special grants totalling \$500,000 each per year were made to the Hall and Florey Institutes for the three years 1974-75 to 1976-77 in addition to funds made available through the NH & MRC. These 'inflation crisis' grants have now been incorporated into the normal NH & MRC support, and are no longer managed by the Department of Health.

39.2.41 The Department (through its Policy and Planning Division) has made funds available through the Health Program Grants arrangements for research covering the development and evaluation of new or different forms of health care, quality assurance processes and cost containment systems in the health services. This research does not duplicate the Planning and Research Program support of evaluation of existing health services, since its particular focus is on the development of new services and their associated evaluation.

39.2.42 The Commonwealth Serum Laboratories Commission (CSL) undertakes research on biological products used for therapeutic purposes. Research on those products which have been prescribed for sale is funded wholly by the Commission. However, under the provisions of the CSL Act, where there is a loss on the Commission's overall operations, expenditure on products which have not been prescribed for sale is reimbursed by the Commonwealth to the extent of the whole of that expenditure or the amount of the loss, whichever is the lesser. Expenditure on research over the last five years has been:

TABLE 39.6

CSL RESEARCH EXPENDITURE 1972-73 TO 1976-77

<u>Year</u>	<u>\$million</u>
1972-73	1.108
1973-74	1.283
1974-75	2.071
1975-76	2.045
1976-77	2.607

39.2.43 CSIRO funds substantial programs of health science research in a number of Divisions. Expenditure in the last three years is shown below. Expenditure for the research by the Division of Human Nutrition, which was established in 1975, is introduced in the year 1976-77:

TABLE 39.7

CSIRO HEALTH RESEARCH EXPENDITURE

<u>Year</u>	<u>\$million</u>
1974-75	0.460
1975-76	1.090
1976-77	2.210

This is a very small fraction of CSIRO's total expenditure, which was \$147.7million in 1976-77.

39.2.44 The Commonwealth funds directly an extensive program of health research at the John Curtin School of Medical Research, Australian National University, through the budget appropriation of the University. The School's total budget for 1977 was just over \$7million.

39.2.45 In addition to the Commonwealth bodies already mentioned, a number of other Commonwealth Departments fund directly health science research carried out within their own organisations. For example, the Departments of Science, Aboriginal Affairs, Veterans' Affairs, Defence and Social Security are all involved in aspects of health science research. The contributions of these Departments are, however, relatively minor.

39.2.46 State governments provide financial support to a wide variety of organisations carrying out health research including departmental organisations, teaching hospitals, educational institutions and independent research institutes. This is an important source of funding, although information on which to assess the overall level of support is not available.

39.2.47 State governments also contribute, on a \$1 to \$2 basis, to the funding of Research and Planning Units established under the H & HSC's Health Services Planning and Research Program. Total State contributions to these units for 1976-77 were approximately \$280,000.

39.2.48 Substantial financial support for health research comes from non-Government sources, including, for example, charitable trusts (such as the Ian Potter Foundation, the William Buckland Foundation, the Clive and Vera Ramaciotti Foundation and the Felton Bequest), specific disease-oriented charities, (such as the National Heart Foundation, the Cancer societies, the Asthma Foundations, and the Australian Kidney Foundation); the Life Insurance Medical Research Fund of Australia and New Zealand; bequests, donations and income from investments; and in some instances, research contracts. Professional medical and dental associations also provide some support.

39.2.49 As mentioned in 39.2.8, significant funds are provided from overseas sources. In some cases, especially with the World Health Organisation, the research carried out in Australia is part of a wider program extending to other countries.

39.2.50 The funds from non-government sources generally flow to the universities and the major independent research institutes, to which this means of funding is of particular importance. For example, of the total income of \$2.9million received by the Hall Institute in 1976, \$1.1million or 38.5%, was received from non-government sources; of the total research expenditure by Melbourne University Medical Faculty in 1975, \$0.98 million or 35.4% was from non-government sources.

39.2.51 Pharmaceutical companies contribute funds to clinical research related to drugs proposed for release in Australia. One pharmaceutical company supports a major research institute in Sydney devoted to a search for potential drugs isolated from marine fauna and flora (see 39.3.22).

39.3 DESCRIPTION OF R&D ESTABLISHMENTS

INTRODUCTION

39.3.1 In general, it can be said that health research in Australia has reached a high level of competence and sophistication, and is in a healthy and vigorous stage of evolution. The major achievements of Australian researchers are receiving international recognition, and Australian research institutes attract research workers and scholars from many overseas countries. Several research centres have become acknowledged internationally as centres of excellence in such fields as virology, immunology, neurophysiology, cardiovascular physiology and pathology, endocrinology and medical ultrasonics.

39.3.2 Before 1973 health research in Australia was almost wholly in the area of biomedical research, with very little research activity in the area of health services. However, with the advent of the Hospital and Health Services Commission and the establishment of its Health Services Planning and Research Program, an adequate level of funds became available for the first time from both Federal and State sources to support research and planning investigations related to health services. This area is now receiving much more attention than previously.

39.3.3 In general, progress in the health services planning and research area was hampered in the past by the lack of research and development policies and the small number of people in Australia with the appropriate experience and training either to generate or conduct useful research projects or to assess proposed research protocols. However, the need for policies in this area has now been recognised at Federal and State levels and there is an awareness of the desirability of commissioning research in areas of major and pressing concern to health authorities.

39.3.4 The burgeoning cost of health care, which in 1976-77 was \$6,254million, demands an adequate level of research into all aspects of the operation and planning of health services as a means of achieving maximum efficiency and the most effective and economic use of available resources. The attainment of such a level of research in this area is becoming increasingly urgent. A brief outline of the main categories of organisations conducting research in health science follows.

UNIVERSITIES

39.3.5 Most health research in the universities is centred on the medical and dental schools and their associated teaching hospitals, with other faculties contributing in areas relevant to their fields of concern. Research activities frequently include interdisciplinary studies involving several institutions and centres. It is common for universities to undertake research and development on behalf of commerce and industry, and in some cases university-controlled companies have been set up for this purpose.

39.3.6 The John Curtin School of Medical Research, a part of the Institute of Advanced Studies of the Australian National University, conducts an extensive program of research on a broad base in several biomedical disciplines, including the interaction of man with his environment. As it is not involved in undergraduate teaching, it functions in many ways like a large research institute.

39.3.7 Each university has a wide range of research interests; this is illustrated by the example set out in Appendix 39.4 which lists the principal research interests of the departments in the Faculty of Medicine at the University of Sydney.

OTHER TERTIARY EDUCATION INSTITUTIONS

39.3.8 Tertiary institutions other than universities are becoming increasingly involved in health research in their particular fields of interest. Research and development is carried out usually by staff members, and often in collaboration with universities and teaching hospitals. As an example of the range of this involvement, the Queensland Institute of Technology undertakes research in applied science related to health, nutrition and dietetics, medical technology, optometry, chiropody, health surveying, clinical laboratory techniques, medical ultrasonics, biomechanics, radiation, and instrumentation.

INDEPENDENT RESEARCH INSTITUTES

39.3.9 The independent research institutes occupy an important and increasingly significant position in the field of health research and

development in Australia. Two institutes, The Walter and Eliza Hall Institute of Medical Research and The Howard Florey Institute of Experimental Physiology and Medicine, are regarded by the NH & MRC as 'centres of excellence', and are supported through institutional block grants.

39.3.10 The Hall Institute, which is associated with the University of Melbourne and the Royal Melbourne Hospital, is involved in fundamental and applied aspects of immunology research, and in cancer research with special emphasis on leukaemia.

39.3.11 The Florey Institute, which is also associated with the University of Melbourne, and with several Melbourne hospitals, is concerned principally with endocrinology. Also included is work on reproduction, salt balance, hypertension, control of the kidney, and hormone synthesis.

39.3.12 Of the other institutes mentioned above (39.2.13), the largest is the Baker Institute devoted to a study of problems of the heart and lungs.

COMMONWEALTH GOVERNMENT

39.3.13 The Department of Health conducts research in its own organisations. The National Acoustic Laboratories carry out research and development into hearing aids and their application to the needs of people, and into the effects of noise on man. The Ultrasonics Institute is concerned with research into the use of ultrasonic radiation in the diagnosis and treatment of disease, and has achieved a pre-eminent position in this field.

39.3.14 The Australian Radiation Laboratory undertakes research and development relating to the public health hazards of ionising radiation, radio-active materials; microwaves and lasers; dose levels from these sources of radiation to which workers and members of the public are exposed; national standards of radiation dose and of radioactivity, and calibration of measuring instruments and systems. It also investigates the physical effects of the use of ionising radiation, radioactive materials, micro-waves and lasers in medical diagnosis and treatment.

39.3.15 The School of Public Health and Tropical Medicine, attached to the University of Sydney, is involved in research into all aspects of public health and preventive medicine. The Institute of Child Health, a part of the School, is particularly concerned with research directed at determining the normal mechanisms of biological function and studying their disturbance in human disease.

39.3.16 The Australian Dental Standards Laboratory conducts research into dental materials and techniques. The National Biological Standards Laboratory undertakes research and development directed at establishing satisfactory standards for therapeutic goods. The Northern Territory Division of the Department of Health is involved in ongoing research in

such areas as the epidemiology of leprosy amongst aborigines, the nutritional status of aboriginal children and health care delivery.

39.3.17 Some other Commonwealth departments are involved in research in very specialised areas of health science. For example, the Medical Section of the Antarctic Division of the Department of Science undertakes research in aspects of medicine relevant to the Antarctic; the Royal Australian Navy School of Industrial Medicine carries out research and development on diving equipment and medical problems affecting divers; and the Australian Army Malaria Research Unit investigates chemoprophylaxis and other means of preventing and treating malaria.

39.3.18 The Commonwealth Serum Laboratories (CSL) carries out extensive research relating to biological products for therapeutic use. The Capital Territory Health Commission is developing a state-like function wherein its research effort is devoted to the development of delivery systems for health care that are appropriate to the needs of the people of the ACT.

39.3.19 The CSIRO has some involvement in health research. Much of the basic biological research with which it is concerned has implication for health science, and it also maintains a Division of Human Nutrition. The Australian Atomic Energy Commission is involved in research in occupational health, radiobiology, radiopharmaceuticals and related fields.

STATE GOVERNMENTS

39.3.20 State government organisations conduct research in a broad range of areas affecting public health. Several research institutes have been set up in the States for this purpose, including for example, the Institute of Mental Health Research and Postgraduate Training in Victoria, the Queensland Institute of Medical Research and the Institute of Medical and Veterinary Science in South Australia.

39.3.21 Following the inception of the Hospitals and Health Services Commission's Health Services Planning and Research Program in 1973, Research and Planning Units have been established in State health authorities (see 39.2.27 to 39.2.33). These units are now making a significant contribution to the planning and evaluation of health services.

PHARMACEUTICAL COMPANIES

39.3.22 Pharmaceutical companies contribute to health research in the normal course of their business operations; however, the bulk of research and development is undertaken overseas. A major exception is the Roche Institute of Marine Pharmacology in Sydney, devoted to a search for potential therapeutic substances derived from Australia's marine fauna and flora, as mentioned in 39.2.52.

APPENDIX 39.1

CLASSIFICATION OF HEALTH SCIENCE DISCIPLINES

- | | |
|---------------------------|-----------------------------------|
| 1. Anaesthetics | 22. Oncology |
| 2. Anatomy | 23. Ophthalmology |
| 3. Bacteriology | 24. Oral Surgery and Dentistry |
| 4. Biochemistry | 25. Orthopaedics |
| 5. Biomedical Engineering | 26. Otolaryngology |
| 7. Cardiology | 27. Parasitology |
| 8. Dermatology | 29. Pathology -Basic and Clinical |
| 9. Endocrinology | 30. Pharmacology and Toxicology |
| 10. Epidemiology | 31. Physiology |
| 11. Gastroenterology | 32. Psychiatry - Child |
| 12. Genetics | 33. Psychiatry - General |
| 13. Haematology | 34. Psychosomatic Medicine |
| 14. Health Economics | 35. Psychology |
| 15. Health Services | 36. Pulmonary Studies |
| 16. Immunology | 37. Radiology and Ultrasonics |
| 17. Medical Entomology | 38. Reproduction |
| 18. Medicine | 39. Rheumatology |
| 19. Neurology | 40. Surgery |
| 20. Nuclear Medicine | 41. Urology |
| 21. Obstetrics | 42. Virology |

NH & MRC GRANTS

The NH & MRC awards a number of distinct types of grants. At present these are as follows:

Research Project Grants

A research project grant can be defined as an award to an institution for the support of a scientific investigation proposed by one of the staff of that institution, this investigation having objectives of mutual interest to the National Health and Medical Research Council, the recipient institution and the investigator. Whilst grants may be made to individual research workers, the institutions are responsible for administration and accounting.

Research projects so supported vary from small, short term single objective studies to large projects devoted to a major medical or health problem studied with the use of several scientific disciplines and with support continuing over several years.

The cost of many items required for the prosecution of the scientific objectives of a project may be charged to the grant made to support it. These include salaries of staff, purchase of equipment, supplies, travel, experimental animals and other discernible direct costs.

NH & MRC Travelling Fellowships

These are, in essence, individual awards which pay stipends, travel and family allowances, and fares, to enable graduates to study overseas for periods up to two years in the fields of medical research, clinical sciences, occupational and public health.

NH & MRC Scholarships

A large amount of research career preparation is facilitated by NH & MRC scholarships. These are awarded to university departments and individuals engaged in research and training in medical or dental specialities. For the most part, the scholars are persons who have completed basic professional studies but who need additional training to gain research skills.

Grants to Research Institutes

Financial support for Australian research institutes of high international standing has been placed on a stable basis. NH & MRC support for these institutes is contingent upon the Council exercising a measure of control over the institutes' activities, including the appointment of senior staff.

At present, the Council supports the Walter and Eliza Hall and the Howard Florey Institutes in this manner.

NH & MRC Research Units

A recent development has been the encouragement given to areas of research considered by the Council to be in need of preferential support. Initiatives have been taken to establish a NH & MRC unit in psychiatric research and by the introduction of Research Fellowship appointments in cardiovascular disease, renal disease and arthritis.

Other Grants

These include grants which do not always support actual research projects but nevertheless provide for investigations of considerable scientific importance. The Council has regularly undertaken important public health surveys to determine the amount of pesticide residues in marketed foods, and has recently sponsored the extension of monitoring to include mercury, cadmium and other heavy metals.

The Council also issues a series of special reports and memoranda, and was instrumental in the development of the MEDLARS system in Australia. Encouragement is offered to NH & MRC grantees to attend scientific congresses in Australia and New Zealand by the payment of travelling expenses, and the Council is currently considering the establishment of a system of research seminars.

UNIVERSITY OF QUEENSLAND - FACULTY OF MEDICINE AND DENTISTRY

SUMMARY OF EXPENDITURE ON RESEARCH 1974-1977(\$)

Department	ARGC	NH&MRC	Drug Companies	University Sources *URG/MBF/ CRF	Qld Cancer Fund	Total# Allocation
Anatomy	11,814	28,117	-	5,000	-	177,150
Biochemistry	251,461	226,817	-	201,387	33,722	876,468
Child Health	-	7,922	-	65,000	-	101,077
Dentistry	-	51,000	-	120,000	-	177,069
Medicine	-	569,939	249,727	190,143	45,966	1,350,680
Microbiology	61,975	91,335	-	117,395	23,892	392,973
Obstetrics & Gynaecology	-	105,456	-	83,681	39,567	266,933
Occupational Therapy	-	-	-	19,373	-	20,273
Pathology	-	35,486	-	99,817	77,225	205,253
Physiology	25,542	132,664	-	143,465	-	336,723
Physiotherapy	-	-	-	44,743	-	67,908
Psychiatry	-	25,531	?	54,174	-	95,708
Social & Preventive Medicine	-	2,236	-	49,211	-	126,240
Speech & Hearing	-	-	-	7,191	-	7,191
Surgery	-	124,954	-	216,315	57,184	446,254
Faculty of Medicine	-	-	-	-	-	230,000
TOTALS	350,792	1,401,457	260,000/	1,496,895	277,556	4,877,900

* University Research Grant/Mayne Bequest Fund/ University Cancer Research Fund.

/ Estimated.

Funds from sources other than those in Columns 2 to 6 are included.

APPENDIX 39.4

THE UNIVERSITY OF SYDNEY

PRINCIPAL RESEARCH INTERESTS OF DEPARTMENTS
IN THE FACULTY OF MEDICINE - 1974-76

DEPARTMENT OF ANAESTHETICS

1. Effects of transfused stored blood on acid-base balance.
2. Physiological effects of induced hypothermia.
3. The effect of local anaesthetics in relief of pain.
4. Metabolism of halogenated anaesthetic agents.

DEPARTMENT OF ANATOMY

1. Muscle research.
2. Brain research.
3. Dental anatomy.

DEPARTMENT OF BEHAVIOURAL SCIENCES IN MEDICINE

1. The dying process; the effect of social support.
2. Psychological aspects of terminal illness.
3. The 'crisis' of first parenthood.
4. The hospital as a social system; a comparison of a surgical and a medical ward.
5. Survey of demographic and attitudinal characteristics of incoming first year medical students.
6. Cerebral dominance in sinistrals.

DEPARTMENT OF MEDICINE

1. Cardiology
 - (a) modern techniques of cardiac imaging.
 - (b) cardiac arrhythmias.
2. Endocrinology and metabolism.
3. Neurology.
4. Respiratory failure.
5. Gastroenterology.
6. Chronic lung disease in Sydney school children and in Papua New Guinea.

DEPARTMENT OF OBSTETRICS AND GYNAECOLOGY

1. Hyperprolactinaemic amenorrhoea.
2. Metabolic studies and oral contraceptives.
3. Pharmacokinetics.
4. Pituitary-ovarian and uterine function in patients with dysfunctional uterine bleeding.

5. Chronobiology of the periparturient period.
6. Pharmacological blockade of the synthesis and actions of prostaglandins.
7. Umbilical plasma steroid levels related to foetal maturity and the parturient process.
8. Sperm histones.
9. Corpus luteum.
10. Compounds in plants regulating fertility in the human.
11. Immunological studies of implantation.

DEPARTMENT OF PATHOLOGY

1. Analysis of the distribution of neoplastic cells following intravenous injection.
2. Real time study of the metabolic requirements for epithelial cell motility in continuous perfusion culture.
3. Analysis of contractile protein composition of migrating epithelial cells.
4. Cellular mechanisms of allo-immune responses in vivo.
5. Bone growth and remodelling.
6. Study of cell biology in skeletal tissues.

DEPARTMENT OF PHYSIOLOGY

1. Central visual pathways in the cat.
2. Visual and auditory attention in the monkey.
3. Visual pathways in the cat and monkey.
4. Rats' visual system.
5. Physiology of the synapse.
6. Skeletal muscle.
7. Biology of myosin.
8. Mechanical factors in atherogenesis.
9. Control of respiration in health and disease.
10. Pituitary and ageing.
11. Renal physiology; micropuncture studies.
12. Exocrine gland function.

DEPARTMENT OF PHARMACOLOGY

1. Actions of drugs which affect the central nervous system. (Several staff members and research students are working in this general area covering drug abuse and behavioural factors).
2. Cardiovascular Pharmacology.
3. Analgesic drugs.
4. Respiratory Pharmacology.
5. Investigation of ingested lead in the Sydney metropolitan area.

DEPARTMENT OF SURGERY

1. Renal transplantation.
2. Organ preservation.
3. Peripheral arterial disease.
4. Peritonitis.
5. The effect of thalidomide on the developing nervous system.
6. A study of amputees.
7. Tumour immunology.
8. Chemotherapy in melanoma.
9. Colo-rectal cancer.
10. Post-operative venous thrombosis.
11. Transplantation of islets of Langerhans.
12. Vagal nerve section in the treatment of peptic ulceration.
13. Ultrasonic imaging of breast and thyroid.
14. Natural history of ischaemic vascular disease of the lower limbs.
15. A comparison of the synthesis and levels of glycosaminoglycans in aged and osteoarthritic human hip cartilages.
16. Studies on the scoliotic disc - attempted correlation of collagen content with degree of curvature and related parameters.
17. Studies on the inhibitory effects of anti-inflammatory drugs on lysosomal enzymes.
18. Studies on the mechanisms of tumour spread using an experimental rat osteosarcoma.
19. Articular neurology of the lumbar spine of the cat.

DEPARTMENT OF PSYCHIATRY

1. The preventive care of bereaved children.
2. Acute compensable injury.
3. Clinical and genetic studies in affective disorders.
4. Clinical psychopharmacology.
5. Endocrine aspects of anorexia nervosa.